The Effects of Simulated Thinning Treatments on Volume and Value of 65- to 80- Year-Old Stands Dominated by Noble Fir on the Warm Springs Indian Reservation, Oregon

by

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Julie D. Stinson, Author

AN ABSTRACT OF THE THESIS OF

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Steven D. Tesch

Very little is known about thinning 65- to 80- year-old noble fir dominated stands. There is a need for such information on the Warm Springs Indian Reservation (WSIR), Oregon where 65- to 80- year-old, high elevation, noble fir dominated stands are being managed. The objectives of this study were to determine the effects of thinning on volume and dollar value as applied to the 65- to 80- year-old noble fir dominated stands on the WSIR. The effects of logging damage on residual stand value were studied. In addition, the effects of branch presence and size on stand value were analyzed.

The West Cascades variant of the Forest Vegetation Simulator (FVS) was used to simulate 8 thinning regimes and growth of six noble fir dominated stands from the WSIR. Stand growth was projected for 50 years. The regimes included low and proportional thinnings to 4 residual stand levels. Residual stand levels were .25 percent, .35 percent,

.45 percent, and .55 percent of maximum stand density. A computer program was written to determine log value using output from FVS, individual tree information on surface characteristics, and current domestic and export log prices and sort specifications.

The volume and value outcomes from the range of thinning regimes were compared to each other and to an unthinned regime. Fifty years after thinning, stands that were lightly thinned increased slightly in total stand volume (includes volume removed at thinning) when compared to the unthinned stand. Increases were 1 percent to 7 percent more of the total volume of the unthinned stand. Heavy thinning decreased total stand volume.

Fifty years after thinning, stands that were lightly thinned increased slightly in total stand value (includes value removed at thinning) when compared to the unthinned stand. Increases were 1 percent to 6 percent more than the total value of the unthinned stand. Heavy thinnings reduced total stand value.

When the dollar value outcomes were calculated in terms of present net worth of the net revenue (logging and hauling costs included) at a range of discount rates and with and without real price increases, the thinning regimes that removed the most volume generally had the greatest present net worth. The regime with the greatest present net worth could be manipulated by changing the discount rate and real price increase.

Analysis of the 40 largest trees per acre showed that the simulated thinning regimes result in very little to no individual tree growth response of the 40 largest trees per acre. The effects of branch presence and size in the first 40 foot log on log value were minimal. The determining factor of log value was size (small end diameter).

These results indicate that thinning 65- to 80- year-old noble fir dominated stands on the WSIR does not significantly increase value or growth. Thinning does bring an immediate economic return. The decision to thin or not should be based on the importance of economic return at various points in time and the desired stand structure.

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1.0 Introduction

The effects of silvicultural practices on value and growth of older (65- to- 80 year old) noble fir (*Abies procera*) are poorly understood. Past research has been targeted at species such as Douglas-fir (*Psuedotsuga menziesii*) and at young stands. The demand for timber harvest and the high value of old noble fir has resulted in pressure to enter and manage upper elevation, mixed conifer stands dominated by noble fir. The need for information on noble fir response to silvicultural practices has risen with the increased focus on managing noble fir stands. Until the present no research has taken place concerning thinning older stands of noble fir.

The broad focus of the overall study concerns silvicultural opportunities for managing 65- to 80- year-old, mid-elevation, mixed conifer forests dominated by noble fir. This study will focus on the growth response associated with thinning and the associated changes in stand value. Value is defined and determined by the economic return from the log market and is influenced by log characteristics such as diameter, length, number of rings per inch, clear wood, and amount of decay and damage. This study presents the possible changes in value and growth that may result from thinning 65- to 80- year old noble fir dominated stands on the Warm Springs Indian Reservation (WSIR).

There are three main reasons for interest in thinning such stands. First, thinning may generate larger-diameter, higher-value trees in the future. Second, thinning may improve tree and stand vigor and increase resistance to insect and disease pests. And third, thinning would provide an immediate source of wood supply that could be used to reduce the rate of old-growth harvest (Tesch et al. 1994).

Two assumptions are made in justifying thinning of such stands. First, it is assumed that larger-diameter logs are more valuable. The goal of silvicultural activities, therefore, would be to generate larger-diameter logs by thinning, which would provide fewer selected crop trees with greater proportion of site resources. The second assumption is that thinning trees of merchantable size, which would otherwise die as a result of competition, provides an opportunity to utilize growth that has already accrued, thus increasing total wood yield from the stand (Tesch et al. 1994).

The noble fir forests within the WSIR are currently a resource of major economic importance. Past and present harvest of old-growth noble fir has proven very profitable. The Confederated Tribes of the Warm Springs Indian Reservation (CTWSIR) is not bound by export regulations and is able to capture significant economic return by selling raw logs on the export market. The supply of old-growth noble fir is limited and the younger noble fir stands are looked upon as a valuable source of logs. The CTWSIR is searching for strategies with which to manage this economic resource.

This study will provide the CTWSIR with information that will help in the formulation of silvicultural management regime planning of these stands. The gain in knowledge from this study will lead to a better understanding of the role that thinning may play in these older noble fir dominated stands. This information will be critical in determining whether thinning is a viable option. The information gained from this study will also be of interest to other forest managers concerned with thinning older conifer stands. This study will provide information on the relationship between thinning and the associated change in dollar value, expressed in both absolute and present net worth terms. This study will also provide information on the effects of logging damage during thinning on future value.

2.0 Objectives

The main objective of this study is to determine the shift in value and growth of crop trees as a function of different thinning regimes applied to 65- to 80- year-old mixed conifer stands dominated by noble fir on the Warm Springs Indian Reservation, Oregon. This study will look at the effects of commercial thinning on:

A. Volume. Volume is defined by tree size. Change in tree height and diameter will determine the change in volume.

B. Value. Value is defined by tree size and characteristics which determine the grade of the log such as species, diameter, length, knot/branch presence, knot/branch frequency, radial growth rate, and amount of defect. Value will be analyzed in current value and in present net worth of net revenue.

C. Stand value when logging damage occurs.

D. Distribution of logs into log small end diameter classes.

E. Stand value when branch presence changes.

3.0 Literature Review

Past research on noble fir stands has been concentrated on young, planted, and managed stands. I was unable to locate any research concerning thinning 65- to- 80 year old stands. A synthesis of the literature pertaining to silvicultural treatments for enhancing tree value, vigor, and growth in 70- to 120-year-old stands dominated by noble fir on the WSIR has been published by Tesch et al. (1994). Tesch et al. (1994) conclude that the minimal amount of information available is enough to encourage further experimentation on silvicultural treatments of noble fir on the WSIR.

Five areas will be addressed in this literature review: A) information on noble fir, B) studies on thinning older conifer stands, C) studies concerning thinning and the associated change in value, D) studies concerning specific wood quality characteristics related to value, and E) studies concerning logging damage and decay of conifers.

3.1 Noble Fir Studies

Noble fir is located primarily in the Pacific Silver Fir *(Abies amabilis)* Zone of Oregon and Washington (Franklin 1982). In the Cascade Range of Oregon, noble fir is found at elevations between 3500 and 5500 feet (Franklin 1982). Noble fir is shade intolerant and because of this consistently plays a pioneer role in stand succession dynamics (Franklin 1982). While initial growth is slow, noble fir continues significant height increment growth at ages over 200 years (Franklin 1990). Noble fir stands generally reach a stage of senescence at 250 to 300 years (Franklin 1982). Most frequently noble fir is found in mixed stands though pure stands do occur (Franklin 1982). Noble fir is found most often with Douglas-fir (*Pseudotsuga menziesii*), Pacific silver fir (*Abies amabilis*), and western hemlock (*Tsuga heterophylla)* (Franklin 1982). In mixed stands noble fir is typically in a dominant position and contributes volume out of proportion to its numbers (Franklin 1982). Noble fir is recognized for its high form factor and strength (Franklin 1990). The cylindrical shape of noble fir gives more volume for a given diameter and height than other conifer species (Franklin 1990). In normally stocked stands of noble fir culmination of mean annual increment (m.a.i.) appears to be relatively late (Franklin 1990). Volume growth and m.a.i. increase rapidly in stands from 70 to 100 years (Franklin 1990). Noble fir continues to grow at or near its maximum rate for a much longer period than Douglas-fir and other associated species (Franklin 1990). Noble fir is relatively free of pests and pathogens (Franklin 1982).

Other characteristics of value associated with old growth noble fir include its fine grain, large diameters, and lack of external knots (Tesch et al. 1994).

Height growth equations and site index estimation curves have been developed for noble fir by Herman et al. (1978). At present there are no published taper equations available for noble fir (Hann 1994). Marshall (1996 in progress) has developed coefficients for a noble fir taper equation using an equation by Kozak (1988).

3.2 Thinning in Older Conifer Stands

3.2.1 Noble Fir

No studies on thinning older stands of noble fir were located in the literature review. However, other studies concerning related species may offer useful information. A limited number of thinning studies in older (100-year-old) stands of Douglas-fir and true fir show that diameter growth of selected crop trees can be enhanced when additional growing space is provided through thinning (Oliver 1988, Williamson et al. 1971, Williamson 1982). Additional studies in younger stands of relevant species also show a positive response to thinning (Cochran et al. 1988, Heniger 1982, Olson et al. 1982, Worthington 1966). These results offer encouragement for further research and study on thinning noble fir stands on the WSIR.

3.2.2 Other True Firs

One study which may be relevant to understanding thinning of older stands took place in a 100 year-old stand of true fir in northern California (Oliver 1988). This stand was dominated by California red fir (*Abies magnifica*), a relative of noble fir. Thinnings were "low" removing the smallest trees in the stand. The low thinnings were to a range of basal area densities. Densities ranged from a control of 367 square feet/acre to 260, 230, 200, 170, and 140 square feet/acre of residual basal area. A response to the thinning regimes was found within ten years. Oliver (1988) reported that diameter growth was significantly related to reserve stand basal area. Trees in the plots thinned to 140 square feet/acre of basal area grew rapidly: 0.32 inches annually compared to 0.12 inches for trees in the unthinned plots. Oliver (1988) found that height growth of crop trees was not significantly influenced by stand density. Oliver (1988) concluded the 100-year-old stand of true firs responded well to thinning. Leaving about 50% of the original basal area resulted in little or no loss of net volume production. Oliver (1988) was cautious about implementing such heavy thinnings unless healthy, full crowned trees can be selected as the reserve trees, because of possible associated effects of windfall.

Many thinning regimes and studies have taken place on young stands of white fir (*Abies concolor*) and grand fir (*Abies grandis*). Cochran and Oliver (1988) have found that these species respond well to heavy low thinning. They suggest that white and grand fir stands, managed at 75% of normal density, produce 93% of the gross periodic annual cubic volume increment of fully stocked stands and stands at 50% of normal density produce 80% of the gross periodic annual increment of fully stocked stands.

A thinning study was installed by Weyerhaeuser Company in 1973 in south-central Oregon in a 50-year-old natural white fir stand (Heniger 1982). This stand was dense and sapling-size. The results of this study may not be pertinent to the larger sized noble fir stands of interest, however, the short-term rate of growth response may be relevant. Low thinnings were done to 2 x 2 meters, 3 x 3 meters, and 5 x 5 meters. Some of the 3 x 3 meter plots were fertilized after thinning. After five years the thinned plots were remeasured. Heniger (1982) reported that white fir will respond to thinning release and that growth rates, particularly on crop trees, can be increased. Fertilization increased average diameter growth for all trees by 36 percent and net volume growth by 32 percent compared to the thinned-only plots.

Another thinning study that involved fertilization took place in northern Idaho. Well-stocked vigorous stands of grand fir were studied over a range of sites, age, and stand densities (1982 Olson and Hatch). Results after eight years showed that the grand fir stands responded to both fertilization and thinning treatments. The authors found that nitrogen applied at 200 lb./acre increased total gross volume growth of inland grand fir stand types over an eight-year post-treatment period. Combined thinning and nitrogen treatments yielded the highest total cubic foot response. Individual tree comparisons indicated thinning produced greater gross volume response than nitrogen alone. Gross volume response to thinning alone was not significant until the third and fourth growing season. The authors suggest a possible "thinning shock" effect. Age-related response was not discussed in this paper. I was unable to determine if any older stands were thinned in this study.

3.2.3 Douglas-fir

There have been several thinning studies of older (60- to- 100-year old) stands of Douglas-fir. These may be relevant to the stands on the WSIR because of the component of Douglas-fir in the mixed conifer stands. The information from Douglas-fir stands may also help support the findings from studies of true fir stands.

In 1952, a thinning study was established in a 110-year-old stand of Douglas-fir in southwest Washington on the Wind River Experimental Forest (Williamson 1982, Williamson 1966, Yerkes 1960, Steel 1954). Stands were thinned to approximately 75% and 50% of normal basal area. Thinnings removed trees from all crown classes, though effort was made to retain the most vigorous dominant and codominants. Williamson (1982) remeasured the plots 19 years after thinning. Williamson (1982) reports that gross growth of all plots, except a lightly thinned one, was about equal to normal gross growth during the 19-year period after thinning. Normal was defined as normal growth for stands with similar site indexes. Williamson (1982) found that average mortality on the control plots was five times greater than on the heavily thinned plots and about three times greater than on the lightly thinned plots. Mortality amounted to 86 percent of gross growth in the control plots and to only 23 to 30 percent of that in the thinned plots. Net growth was much less than normal in the control plots. Lightly thinned stands averaged 119 percent of normal net growth and heavily thinned stands averaged 136 percent. Some trees, in each of the studied plots, were sectioned by stem-analysis techniques. This analysis revealed that the ratio of volume growth for the 19 years after thinning to that for the 19 years before thinning was 30 percent greater in the heavily thinned plots than in the controls and 8 percent greater in the lightly thinned plots than in the controls. The thinning benefited volume growth in all crown classes and it benefited the suppressed trees more than the others. Dominant trees responded less than suppressed trees, while codominant and intermediate trees had the lowest relative responses. In conclusion, Williamson (1982) reported that thinning in these stands salvaged trees that would have died in the future and also stimulated individual tree growth response.

In the Oregon and Washington Cascades, seven study areas were analyzed where thinnings had taken place when stands were between the ages of 68 and 110 (Williamson and Price 1971). The thinning regimes included low thinnings and removal of trees in the crown at a range of densities. The focus of the study was on volume growth response. Unfortunately, data on change in diameter was not part of the study. Williamson and Price (1971) reported that the rate of response to thinning decreases with stand age. The authors report that the relative increase in basal area after thinning was probably a reflection of differences in age of the stands when they were thinned (the older stand had less basal area increase) rather than an effect of thinning intensity or residual basal area. The authors report that crown thinnings primarily benefited gross basal area growth of larger trees, while low thinnings primarily benefited gross basal area growth of other lower crown-class trees. The authors report that thinning was found to inhibit mortality by bark beetles. Williamson and Price (1971) conclude that growing stock can be varied from 60 to 90 percent of normal and residual trees will maintain near-maximum site utilization. The authors state that emphasis should not be placed on removing primarily suppressed and intermediate trees. They recommend that thinnings in older stands be concentrated on dominant and codominant trees whose removal will relieve clumpy conditions and provide release to better codominants and dominants.

Four 60- year-old Douglas-fir stands, located on the Olympic National Forest, were thinned in 1934 and 1937 (Worthington 1966). Basal areas removed were 31 percent and 37 percent on moderately thinned plots and 44 percent and 50 percent on heavily thinned plots. Low thinning mainly occurred, however, some dominants and codominants were also removed. Second and third light thinnings took place in 1949 and 1958 to improve spacing and salvage dead and dying trees. Thirty years of growth after the initial thinning show that the heavy thinning substantially depressed gross volume growth increment, however, the moderate thinning reduced gross volume growth increment only slightly. Average stand diameter growth was 23 percent greater on thinned areas: 3.48 inches compared to 2.65 inches on the unthinned stands. Worthington (1966) states that while there was an actual increase in growth, part of the difference is the effect of eliminating most of the suppressed trees in initial thinning. The author reports that the main advantages to the thinnings were the salvage of mortality, reallocation of stand growth potential, and realization of earlier returns through thinning.

In the literature where the focus was a general discussion on thinning Douglas-fir the authors have reported the major source of gain from thinning to be the harvest of merchantable trees otherwise lost to mortality (Reukema and Bruce 1977, Worthington and Staebler 1961).

3.3 Value Response to Thinning

Existing studies have focused on volume responses to silvicultural practices rather than changes in dollar value and tree characteristics which define this value. Briggs and Fight (1992) developed a model to assess the effects of silvicultural regimes on Douglas-fir log quality and stand value. This information is not directly applicable to noble fir but may lend itself to developing a system to measure changes in value of noble fir.

3.4 Wood Quality Characteristics Related to Value

The characteristics which determine domestic log grades are log length, log small end diameter, defect, radial growth rate, branch presence, and branch size (Official Log Scaling and Grading Rules 1992). Radial growth rate is measured by the number of rings per inch at the small end of a log. The following information on export log sorts is from Chris Beckett of Pacific Lumber and Shipping, Portland, Oregon (personal communication, 1996). Export log sorts take into account the same characteristics as the domestic log grades plus surface and appearance characteristics such as bark and uniformity among groups of logs. High value noble fir export sorts require old-growth noble fir with high ring count (throughout the diameter) and deeply fissured bark. Second growth noble fir do not meet the requirements of the high value noble fir sorts because they lack the old growth characteristics which define these sorts, specifically, ring count and bark characteristics.

In addition to log size, rings per inch, and defect, the presence of branches or branch stubs is very important when determining the grade of a log. Little is known about how long it takes branches to decay and branch stubs to heal over.

In order to determine the progress of natural pruning, Paul (1947) studied approximately 1,000 knots from 100-year-old and 150-year-old Douglas-fir stands, site quality II and IV, in Lane County, Oregon. The author found that in both stands, dead branches extended through the bark along the entire merchantable length of most of the trees studied. The number of knots in butt logs averaged 3.5 per lineal foot of log length on site II and 6 per lineal foot on site IV. In addition, there were 1.6 and 4.1 pin knots

(knots less than 0.3 inch in diameter) per lineal foot, respectively, in the same logs from the two sites.

A study was done on natural pruning in second-growth Douglas-fir (Kachin 1939). The location of the study was not included in this Pacific Northwest USFS Forest Research Note. The author reports that it takes about 60 years from the death of a branch to its complete occlusion, generally leaving an enclosed black or loose knot 6 or more inches long. Kachin (1939) states that it take more than 100 years for Douglas-fir to develop a completely surface-clear 16 foot log.

Paul (1959) reports that as a rule, true firs prune themselves naturally after lateral branches have been killed by shading. He does not, however, give any time frame to this statement.

A study on natural pruning of black spruce (*Picea mariana*), red spruce (*P. rubens Sarg.*) and balsam fir (*Abies balsamea*) took place in Quebec (Vezina and Paille 1967). The authors report that basal area and diameter at breast height (DBH) are related to the percentage of the bole covered by dead branches. This is because high densities, measured by basal area and DBH will result in rapid dying of the lower branches but will not necessarily accelerate the rate at which dead branches fall off. Once the branches are dead they do not fall until weakened by fungi or similar agencies. Vezina and Paille (1967) conclude that while parameters of trees and stands that were measured can account for the rate of dying of branches they have little effect on the rate of deterioration of dead branches.

No published studies of pruning in older, noble fir stands were located. Most studies focus on young managed plantations of radiata pine (*Pinus radiata*) and Douglas-fir. Pruning the butt log in older noble fir stands would be unconventional in that it would remove primarily dead limbs that had not self-pruned (Tesch et al. 1994). Diameter growth is needed after pruning before clear wood can be formed. A rule of thumb, in order to produce high grade veneer, is that an average of 3.9 inches of diameter growth is required to heal over the branch stub left after pruning and to compensate for grain distortion (Cahill et al. 1986). Depending on pruning costs, the time available until final harvest, and log grades and wood values, the practice of such pruning may or may not be practical.

3.5 Log Prices

Prices of domestic log grades and export sorts are reported by private publications such as “Log Lines”. To determine log prices in the future, projections are made based on historical trends (Haynes et al. 1995).

3.6 Logging Damage and Associated Decay

When residual trees are wounded during thinning, decay is a clearly associated result. True firs are thin-barked and highly susceptible to logging damage and are frequently invaded by decay fungi (Aho et al. 1989, Wright and Isaac 1956). Several studies have investigated the relationship between the damage from thinning and the amount of resulting decay. At present there are no published studies looking specifically at noble fir, although currently there is such a study taking place on the WSIR (personal communication, Filip, 1996). While the studies undertaken thus far focus on true firs, the information they present is useful in understanding the potential effects of thinning damage to noble fir.

Wright and Isaac (1956) studied decay following logging injury to western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Pacific silver fir, and grand fir. This study looked at 7 study areas on the Cascade Range. Trees with logging injuries were dissected and the extent of the decay was traced. Wright and Isaac (1956) found that root injuries and scars close to the ground showed a greater incidence of decay than injuries occurring 4.5 feet or more above ground. All scars larger than 7 square feet in area were infected, whereas less than half of the scars 1 square foot or smaller had decay in them. The authors also found that occurrence of sunscald was greater in heavily thinned stands as opposed to lightly thinned stands.

A study on logging damage was established in commercially thinned, naturally established young-growth true fir stands in the Lassen National Forest in northern California (Aho et al. 1983b). The author reports that significant damage occurred to residual trees in stands using conventional harvesting methods. Wounds resulted on 22 percent to 50 percent of residual trees. Of the residual trees in the conventionally logged stands, 8 percent to 15 percent were so badly damaged they were no longer suitable for crop trees. Logging damage was reduced substantially in stands thinned using techniques designed to reduce injuries. The number of trees wounded was lowered to 5 percent to 14 percent. All of the trees wounded were infected by decay fungi. Individual tree decay losses associated with wounds were 14 percent of Scribner board foot volume. Aho et al. (1983b) reports that present and original wound size and wound age were the most important characteristics relating to the amount of decay. The author states that decay was also significantly related to position of the wound relative to the ground; wounds in contact with the ground had more decay than those originating higher in the tree.

In 1981, 562 white and red firs with wounds were sampled in 28 commercially thinned stands in the Klamath and Tahoe National Forests in northern California (Aho et al. 1989). The stands were all naturally established and had been thinned 2 to 25 years earlier by conventional logging methods. The relationship between amount of decay and wound characteristics (size, age, height, condition, aspect) by tree species and forest location was established using regression analysis. No statistical difference was found between white and red firs. Differences were found between forest locations. Between 90 to 100 percent of all trees became infected by decay fungi. Individual tree Scribner board foot volume losses caused by decay associated with wounding were 5.7 percent on the Klamath and 7.6 percent on the Tahoe. The authors found that the most important wound characteristics related to associated decay were wound size (original and present) and wound age. Aho et al. (1989) stresses that wounding of residual trees must be minimized in true fir stands to prevent wound-induced decay that could nullify the benefits of thinning.

A method for estimating the percentage of crop tree volume caused by decay fungi was developed for advanced white and grand fir regeneration in eastern Oregon and Washington (Filip et al. 1983). The same equation was used for estimating the percentage of crop tree volume decay in 40- to 90- year-old grand fir stands in the Clearwater Region of Northern Idaho (Filip et al. 1990). These equations include the following variables: mean crop tree total age, percentage of trees with one or more wounds, and stand aspect. The driving coefficient is mean crop tree total age.

There are published studies that outline steps to prevent stem damage during thinning activities (Aho et al. 1983a, 1983b). Oregon State University Extension agents also have documented the procedures for prevention of tree wounding during thinning.

4.0 Description of Study Area

The Warm Springs Indian Reservation is located in central Oregon (Figure 4.1). The six areas of interest in this study are upper elevation (3900-4900 ft), noble fir dominated stands located on the east slope of the Cascade Mountains in the northwest portion of the WSIR. The selected stands are located in Wasco County (Township 5 South, Township 6 South, Range 9 East).

The forest type is associated with the Pacific Silver Fir zone (Franklin 1982). The six stands of interest are comprised of naturally regenerated 65- to 80-year-old mixed conifers. The 100 year noble fir site indexes (Herman et al. 1978) of the six selected stands range from 83 to 122. The species composition of these stands consist primarily of noble fir (43 percent to 85 percent) and Douglas-fir (9 percent to 27 percent) with small amounts of white fir, mountain hemlock (*Tsuga mertensiana*), and silver fir. Stands are primarily even-aged with mean stand ages ranging from 65 years to 80 years. Some of the stands have a small amount of residual old growth Douglas-fir in the overstory. There is very little understory vegetation. The plant associations of these stands are ABAM/CLUN (Abies amabilis/Clintonia uniflora - silver fir/queencup beadlily), TSME/XETE (Tsuga mertensiana/Xerophyllum tenax - mountain hemlock/beargrass), and ABGR/SYMPH (Abies grandis/Symphoricarpos spp. - grand fir/snowberry) (Marsh et al. 1987).

Annual precipitation is roughly between 50 and 70 inches (Marsh et al. 1987). Most precipitation falls during the winter as snow, accumulates as snowpack and melts during May to July (Marsh et al. 1987). Summer precipitation is usually light with very little rain from July to September (Marsh et al. 1987).

The natural disturbance regime of this area appears to include fire and possibly wind events. The dense, naturally regenerated, even-aged stands, are probably the result of stand replacement fires.

The soils types of these stands include the Pinhead-Jojo Complex, the Mackatie-Kutcher Complex, and the Howash Complex (personal communication, Chris Gannon, Water and Soil Resources, WSIR, 1996). These soils are deep, well-drained sandy loam. Timber production, wildlife habitat, and watershed are major uses of these soil types on the WSIR (personal communication, Chris Gannon, Water and Soil Resources, WSIR, 1996).

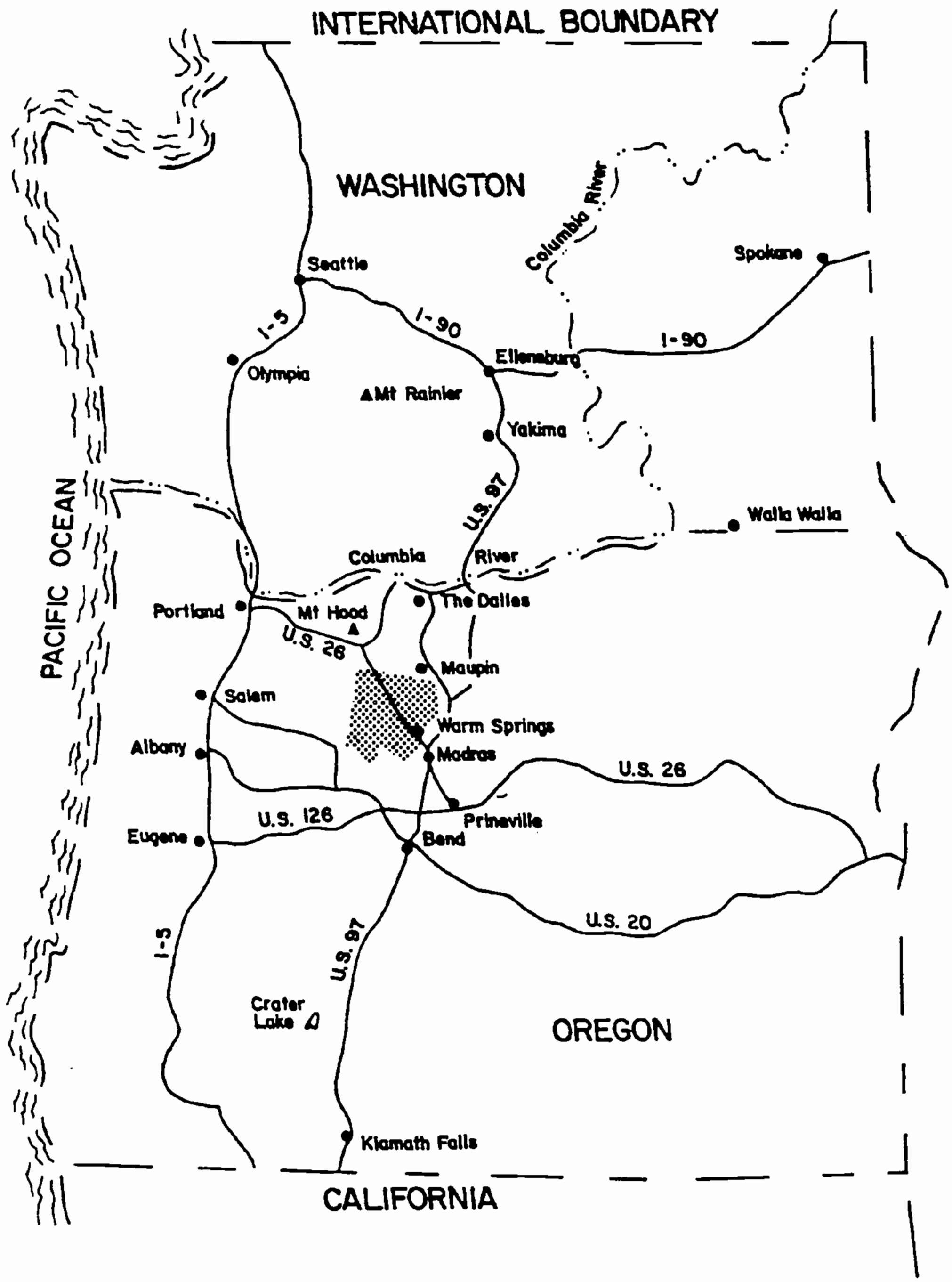


Figure 4.1 Location of Warm Springs Indian Reservation.

5.0 Methods

Several steps were taken in order to determine the effects of thinning on volume and value. These procedures are briefly outlined in section 5.1 with full descriptions of each procedure in sections 5.2 - 5.10.

5.1 Outline of Procedures

Step 1. Data collection. Stands on the WSIR were selected for this study. Tree and stand data were collected from these stands.

Step 2. The performance of the West Cascades variant of the Forest Vegetation Simulator (FVS) growth model was evaluated. Adjustments were made to FVS growth model keyword files to improve growth model performance.

Step 3. The West Cascades variant of FVS was used to simulate thinning regimes and growth of the selected stands.

Step 4. Value and volume information was calculated using output from FVS in conjunction with a computer program that I wrote called LOGTABLE.

Step 5. The effects of thinning on stand volume were analyzed.

Step 6. The effects of thinning on the mean diameter at breast height, mean total height, and mean live crown ratio of the 40 largest trees per acre were analyzed.

Step 7. The effects of thinning on stand value and present net worth of stand net revenue were analyzed.

Step 8. The effects of logging damage to residual trees on stand value were analyzed.

Step 9. The effects of thinning on the diameter distribution of log small end diameters were analyzed.

Step 10. The effects of branch presence, in the first 40 foot log, on stand value were analyzed.

5.2 Data

5.2.1 Stand Selection Method

Stands were selected to meet the following criteria:

1. Species composition with basal area greater than 30% noble fir.
2. Basal area greater than 250 square feet of basal area per acre.
3. No thinning entry within the last 25 years.

5.2.2 Data Collection

Data were collected in a two stage sampling procedure. The first stage consisted of establishing 15 to 20 plots (depending on the size of the stand). Plots were established in a systematic fashion to cover the variation in the stands. Variable plot sampling was used with a basal area factor (BAF) of 40. In the first stage, plot center was marked and each "in" tree was tagged. Diameter at breast height (DBH) was measured with a diameter tape to the nearest tenth of an inch. The species of each tree was recorded.

Borderline trees were measured. In the second stage, trees were sorted into 2 inch diameter classes and trees were selected from each class using a random number table. The number of trees selected from each diameter class was weighted by the number of trees in each class. Thirty-seven to 46 trees were selected per stand. The stands were revisited and measurements were taken from selected trees. Total height (HT) and live crown ratio (LCR) were measured to the nearest foot with a Relaskope. Increment bores were used to determine age at breast height and growth rate. Trees were bored at breast height (4.5 feet) at points facing plot center. Surface characteristics, estimated size of branches, frequency of branches (greater than or less than one per foot), height of first live branch, and defect were recorded and later used to determine grade. Elevation, aspect, and slope were recorded for each stand.

One hundred year-noble fir site indexes (Herman et al. 1978) were calculated for each stand using a sample of eight undamaged, dominant, noble fir from each stand. Reineke's stand density index (SDI) was also calculated for each stand (Reineke 1933). Reineke's SDI is a measure of density of growing stock. Reineke's SDI is based on the predictable relationship between quadratic mean diameter and the trees per unit area.

5.3 Forest Vegetation Simulator Growth Model

Version 6.1 of the Forest Vegetation Simulator (FVS) growth model (formerly known as Prognosis) was used in this analysis to simulate thinning regimes and stand growth. FVS is an individual tree, distance independent, empirical growth and yield model developed by the USDA Forest Service (Stage 1973, Wykoff et al. 1982, Wykoff

1986). The West Cascades variant (Johnson 1992) of FVS was used in this analysis. The West Cascades variant covers the geographic location of the stands and is the only variant available with a noble fir component. The noble fir component of this variant was developed from 1,555 observations primarily from the Mount Hood and Willamette National Forests in the 3000-6000 foot elevation range (Johnson 1992).

The diameter increment growth function of the West Cascades (WC) variant includes the following variables: species specific constant adjustments, species dependent regression coefficients, site class, basal area of the subject tree, diameter at breast height (DBH), ratio of crown length to total tree height, basal area in trees larger than the subject tree, stand elevation, stand aspect, stand slope, stand location, crown competition factor on a sample subplot, and the relative height of the 40 biggest trees by DBH (Johnson 1992). Some of the species specific regression coefficients are equal to zero. The effects of dominance, crown ratio, and stand density play important roles in diameter increment prediction. The most important variable in predicting diameter growth is the DBH of the tree in question. The other variables have very little weight in the calculation. The largest increments are attained by dominant trees with large crowns in open stands (Wykoff 1982). Diameter increment predictions decrease as crowns shorten, density increases, and the tree is subordinated (Wykoff 1982).

The height growth model in the WC variant uses a technique of modified potential height growth (Johnson 1992). Published site curves were used to construct site curves for the WC variant (Johnson 1992).

Crown change in the WC variant is calculated at the end of each projection cycle. A weibull distribution of crowns is calculated for the stand given the species position of the tree in the stand and the stand density (Johnson 1992). At the end of each projection cycle there will be a new relative position in the stand and a new stand density (Johnson 1992). The wiebull distribution with this new information produces the value for the tree's crown (Johnson 1992). With thinning the crown might be expected to lengthen (Johnson 1992).

The mortality model in the WC variant is driven by the value for maximum stand density index (Johnson 1992).

To determine the quality of the results of the WC variant of FVS when used for this study, the growth and mortality components of the model were examined in the following manner:

Mortality from ten Continuous Forest Inventory (CFI) plots from the WSIR was compared to mortality projected by FVS when using the same initial data as the CFI plots. See page 86 in the Appendix for CFI plot location and specifications. The CFI plot data were minimal. Only seven plots had greater than 30 percent noble fir. The CFI plot data consisted of an initial measurement period in 1974 and two remeasurement periods in 1979 and 1988. DBH, species, and mortality were the only measurements I used from the CFI data. Height information from the CFI data set was inadequate for use in this comparison because it was taken on so few trees. Data on mortality is also questionable as it occurred only in the 1988 remeasurement period. Despite the poor quality of the data, it was the best available. It provided a reference data set to adjust the growth model parameters in the West Cascades variant of FVS and to build a comfort level with the growth model.

The actual mortality of trees per acre was compared to predicted mortality for one 9 year period. The FVS keyword, BAMAX, drives mortality. I selected a BAMAX level, for each individual stand, that on average produced similar stand mortality to the average mortality level from the CFI plots. The BAMAX level selected had the lowest mean residuals between the actual mortality and the predicted mortality. A BAMAX level of 380 was selected for all stands. The default for this model is 300. Richard Tech, USDA Forest Service, Fort Collins, Colorado, recommended using a higher BAMAX than the default and said that local use had determined that 300 was too low (personal communication, 1996).

Growth increment performance of the model was studied by comparing the last ten year growth of selected trees from the 6 stands in this study to the ten year growth predicted by FVS for these same trees. This comparison is for the growth period from 1985 to 1995. The FVS growth model underpredicted growth. The FVS keyword, BAIMULT, drives diameter growth. Adjustments to BAIMULT were made on an individual stand and species basis. The adjustment that produced the lowest mean residual between the actual growth and the predicted growth was selected. See page 86 in the Appendix for BAIMULT adjustments.

5.4 LOGTABLE Program

In order to analyze the outcomes of the thinning regimes in terms of logs and dollar value as well as volume, a computer program was developed which calculated log data from tree data (LOGTABLE). This program combines the FVS "treelist" after growth and thinning simulations are completed with a file containing information on branch presence, branch frequency, and branch size for each individual tree. The LOGTABLE program then performs the following functions:

A. Bucks logs into forty foot lengths.

B. Calculates small and large end diameters inside bark for each log.

C. Calculates gross Scribner board foot volume for each log.

D. Calculates gross cubic foot volume for each log

E. Grades logs according to the Official Rules for Log Scaling and Grading Bureaus (1982 edition, 1992 reprint). The domestic log grades are assigned to each log based on the scaling diameter of the log, log length, branch presence, branch size, and the number of rings per inch. Defect is not taken into account.

F. Assigns each log into the appropriate sort with the greatest dollar value. The sorts include export log sorts and some domestic log grades. When all of the necessary specifications are met each log is placed into the highest value sort. The sorts are determined by the following specifications: domestic log grade, small end diameter, log length, and number of rings per inch. See table 5.1 for sort specifications.

Explanation of Table 5.1:

Species. Species are broken into three groups: noble fir, Douglas-fir, and white woods. White woods include hemlock and true firs.

Sort Code. The sort code is a reference code to the LOGTABLE program.

Market. The market species whether the logs are sold domestically or exported.

Domestic Grade. The domestic grade refers to the minimum grade that each log would need to meet in order to be in a specific sort.

Minimum Small Diameter. This is the minimum diameter, of the small end of the log, required for a log to be in a specific sort. Some sorts have a minimum and a maximum diameter.

Minimum Length. This is the minimum length required for a log to be in a specific sort.

Minimum Rings per Inch. If a sort has a rings per inch requirement, this is the minimum number of rings per inch required. A sort without a rings per inch requirement would have a dash in this column.

$/MBF. The number of dollars per thousand board feet for a specific sort.

Table 5.1 Sort specifications and prices as of spring 1996.

	Sort		Domestic	Min. Small	Min.	Min. Rings/	
Noble fir	**Code**	**Market**	**Grade**	**Diameter**	**Length**	**Inch**	**$/MBF**
	1	Domestic	P/1S	24"	16'	--	$ 1,800
	2	Domestic	SM	16"	17'	6	$ 950
	3	Domestic	2SA	24"	12'	--	$ 900
	4	Domestic	2SB	16-23"	12'	--	$ 800
	5	Export	2S+	14"	12'	--	$ 750
	6	Domestic	2SC	12-15"	12'	--	$ 620
	7	Domestic	3S	6"	12'	--	$ 535
	8	Domestic	4S	6"	--	--	$ 390
Douglas-fir	1		(Old growth)	> 25"	--	--	--
	2	Export	2S+	12"	20'	--	$ 1,150.0
	3	Export	SM	8-11"	34'	--	$ 945.0
	4	Domestic	SM	16"	17'	6	$ 790.0
	5	Domestic	2SA/B	16-24"	12'	--	$ 740.0
	6	Domestic	2SC	12-15"	12'	--	$ 665.0
	7	Domestic	3S	6"	12'	--	$ 600.0
	8	Domestic	4S	6"	--	--	$ 500.0
White wood	1	Domestic	P/1S	24"	16'	--	$ 1,800
	2	Domestic	SM	16"	17'	--	$ 700
	3	Export	2S+	8"	20'	--	$ 650
	4	Domestic	2S	12"	12'	--	$ 620
	5	Domestic	3S	6"	12'	--	$ 535
	6	Domestic	4S	6"	--	--	$ 390

G. Calculates dollar value for each log. Log prices are from Dan Larson, Manager - Log Sales, Warm Springs Mill (personal communication, 1996). See table 5.1 for prices.

H. Generates the above information in a summary format on a per acre basis by species and sort at 10 year intervals.

I. Generates a table with a diameter distribution of log small end diameters at 10 year intervals.

Assumptions made in LOGTABLE program:

A. Log length = 40 ft. This log length was used because 40 feet is the log length preferred by export market log buyers at present.

B. Stump height = 1 ft.

C. Trim allowance = 1 ft.

D. Minimum top diameter = 6.0 inches.

E. Rings per inch are greater than or equal to 8 rings per inch. This assumption is based on rings per inch data collected from 35 felled trees on one of the selected stands. Rings per inch in the outer one third of the small end diameter were always greater than or equal to 6 rings per inch and 80 percent of the measured logs had greater than 8 rings per inch. The ring count requirement for No. 1 Sawmill grade Douglas-fir is 8 rings per inch. For No. 3 Peeler grade Douglas-fir and Special Mill grade - all species, the ring count requirement is 6 rings per inch.

F. Branches. The assumption was made that the branch information (frequency and size) taken in 1995 remains the same throughout the simulated growth period. Not enough is known about branch occlusion to project the rate at which branches die, break, and branch stubs heal over.

G. Defect. No defect was accounted for or removed.

H. Old-growth Douglas-fir. Douglas-fir greater than or equal to 25.0" DBH were not graded or put into sorts. The variability in the quality of the old growth

Douglas-fir ranged from cull logs to logs of high value. This wide variability made it difficult to accurately determine the value of old growth Douglas-fir logs. For this reason, I did not attempt to determine the value of these logs. The volume is calculated and is included in the total stand volume. Stand values reported do not include the value that would be gained from the harvest of the old growth Douglas-fir timber.

The following equations were used in this program:

1) Noble Fir Taper and Bark Thickness - David Marshall (data on file at Oregon State University)

2) Douglas-fir Taper and Bark Thickness - Walters and Hann (1986)

3) Scribner Board Foot Volume Equations - Bell and Dilworth (1988)

4) Smalian Rule Cubic Foot Volume Equations - Bell and Dilworth (1988)

5.5 Description of Thinning Regimes

Thinning regimes were simulated for each of the six stands using the West Cascades (WC) variant of the FVS growth model. The FVS growth model allows the user to define the type, amount, and time of thinning regime. Because the objective of thinning these stands was to produce larger trees and maintain or improve stand health, the regimes included low thinning (from below) and proportional thinning. Low thinning removes the smallest trees in a stand. These are the trees most likely to be suppressed or to die from suppression. Proportional thinning removes trees across the entire range of tree diameters. Stand growth was projected for 50 years.

Stands were thinned low and proportionally to .25, .35, .45, and .55 of maximum stand density index (MAX SDI). The maximum SDI used was 520. This is the maximum SDI used by the WSIR Bureau of Indian Affair (BIA) foresters in these forest types (personal communication, John Arena, 1996).

5.6 Methods Used For Analysis of Forty Largest Trees Per Acre

In order to determine the effects of thinning on individual tree growth the mean DBH, mean HT, and mean LCR of the 40 largest trees per acre were calculated for each stand and each regime.

5.7 Methods Used for Present Net Worth Analysis of Stand Value

In order to evaluate the projected value of various regimes, the present net worth (PNW) of the total net revenue was calculated. These calculations include initial revenue from commercial thinning, revenue from the final harvest, all logging costs, and all hauling costs. Discount rates of 4 percent, 7 percent, and 10 percent were used for this exercise. The lowest discount rate of 4 percent is considered a low risk discount rate and is what the Forest Service is presently using (personal communication, Claire Montgomery, 1996). The Office of the Management of the Budget is using 7 percent and the forest industry discount rate is often higher (personal communication, Claire Montgomery, 1996). Logging costs were set at 40 dollars/thousand board feet (MBF) (Kellog et al. 1991) and hauling costs were set at 67 dollars/MBF (personal communication, John Arena, 1996). Prices used to determine timber value were from

Dan Larson, Manager - Log Sales, Warm Springs Mill (personal communication, 1996). For this exercise the present net worth was calculated with two scenarios concerning price increase. The first scenario assumes that prices stay the same and the second assumes a 1 percent price annual price increase. The 1 percent annual price increase is similar to price increase projections from the RPA Assessment (Haynes et al. 1995). Carrying costs are assumed to be the same on a per acre basis across the various regimes. Given this assumption the economic effect on all treatments would be the same; for this reason they are not included in this exercise. Inflation has been disregarded because real rates were used. This evaluation is based on the present value of a single sum. Soil expectation value (SEV) was not calculated in this analysis. This is because revenue was considered as coming at only one point in time in the future. Reforestation costs were not included in this exercise. The following equation was used to calculate present net worth :

$$Vo = Vn / (1 + \text{discount rate})^n$$

Where

Vo = Present Net Worth

Vn = Future Value

n = length of period

5.8 Methods Used for Logging Damage Sensitivity Analysis

To evaluate how levels of logging damage effect stand value a sensitivity analysis was done on one stand (LW7). A range of damage levels to residual trees were assumed. These included 0 percent, 20 percent, 40 percent and 60 percent. Two different equations were used to calculate decay loss. First, an equation to calculate individual tree loss (Aho 1983b, 1989), and second, an equation to calculate stand level decay loss (Filip et al. 1983, 1990).

5.8.1 Individual Tree Damage

An individual tree volume loss of 8 percent of the board foot volume per individual tree, over the 50 year period, was assumed. This number was based on averages from studies on damage losses to other true firs (Aho et al. 1983b, 1989). An average price per board foot was calculated for the stand by dividing the total stand value by the total stand volume (after subtraction of old growth Douglas-fir volume). This average price per board foot is conservative because most of the damage volume loss would be in the first log which is the most valuable. The following equations were used to determine stand volume and stand value at year 2045 with deductions for levels of thinning damage:

BDFTLOSS = (DAMAGE %) * (LOSS %) * (VOL1)

VAL2 = VAL1 - (MEANVAL) * (VOL2)

Where

VOL1	=	Stand Volume Year 2045 (BD FT)
BDFTLOSS	=	Board foot volume loss due to damage
VAL1	=	Stand Value Year 2045 ($)
VAL2	=	Stand Value Year 2045 after damage loss deduction

MEANVAL = Mean Value/Board Foot at year 2045 ($)

DAMAGE = % Residual Stand Damage (the percent of the residual stand that was damaged)

LOSS = % Volume Loss due to logging damage

For example, with 20 percent of the trees in a stand damaged:

BDFTLOSS = (.20) * (.08) * (42,541.0 BD FT)

BDFTLOSS = 680.656 BD FT

VAL2 = $31,676.1 - (680.656 BD FT) * ($0.8163)

VAL2 = $31,120.5/Acre

5.8.2 Stand Level Damage

The following equation by Filip (1983) was used to estimate the percentage of crop tree decay loss:

LOGN (DECAY VOLUME CUBIC FT %) = 1.8219 LOGN * (AGE) + 0.8386 * LOGN * (WND%) - 0.4151 * (ASP) - 10.4222

Where

AGE = Mean crop tree total age

WND% = Percentage of crop trees with one or more wounds or conks

ASP = Stand aspect (0=N, NW, NE, W; 1 = S, SE, SW, E)

LOGN = Natural logarithm (R**2 = 0.70, SE = 0.79)

DECAY VOLUME BD FT% = DECAY VOLUME CUBIC FT % * 2.7

For example, with 20 percent of the trees in a stand damaged:

LOGN (DECAY VOLUME CUBIC FT%) = 1.8219 LOGN * (117) + 0.8386 *

LOGN * (20%) - 0.4151 * (1) - 10.4222

LOGN (DECAY VOLUME CUBIC FT %) = -3.51076

DECAY VOLUME CUBIC FT % = 2.98 %

DECAY VOLUME BD FT % = 8.07%

Where

AGE = 117

WND% = .20

ASPECT = 1

Board foot loss is calculated with the following equation:

BDFTLOSS = DECAY VOLUME % * VOL1

VAL2 = VAL1 - (BDFTLOSS) * (MEANVAL)

For example:

BDFTLOSS = 0.0807 * 42,541.0 BD FT

= 8508.2 BD FT/Acre

VAL2 = $31,676.1 - (8508.2 BD FT) * ($0.8163)

= $24,730.8/Acre

Where

DECAY VOLUME BD FT % = 8.07%

MEANVAL = $0.8136

VAL1 = $31,676.1

VOL1 = 42,541.0 BD FT/Acre

5.9 Methods Used for Log Small End Diameter Distribution

In order to determine the effects of thinning on the distribution of log small end diameters I studied the change in distribution over time, for one stand (LW7) and all regimes.

5.10 Methods Used for Branch Retention Analysis

To determine how branch presence affects stand value, an analysis was done on one stand (LW7). The difference in value was compared between two simulated branch removal treatments and a control. In the first treatment all branches in the first log were removed. In the second treatment some branches in the first log were removed. If branch frequency was less than one branch per foot in 1995, the branch status was changed to zero. If branch frequency was greater than one per foot, branch frequency was changed to less than one per foot. If there were no branches present the case remained the same. These two treatments were compared to a control where branch presence remained at the original 1995 level. For all treatments branches above the first log remained at the original frequency.

6.0 Results

6.1 Summary of Collected Data

Six stands were selected that met the desired specifications. These stands are Beaver 287 (B287), Long Willow 7 (LW7), Long Willow 18 (LW18), Long Willow 37 (LW37), Long Willow 452 (LW452), and Mount Wilson 224 (MW224). See page 87 in the Appendix for stand locations and WSIR stand identification numbers. Characteristics of 1995 stand conditions are summarized in tables 6.1 through 6.8. Species are abbreviated: NF = noble fir, DF = Douglas-fir, and OT = other species.

Table 6.1 Elevation, aspect, slope, site index, and mean age.

Stand ID	Elevation	Aspect	Slope	Site Index	Mean Age
B 287	4800-4900	N 360	0-5%	83	76
LW 7	4650-4750	S 180	5%	120	67
LW 18	4500	S 180	0-5%	122	73
LW 37	4600-4800	SW 225	15%	112	79
LW 452	4900	SE 135	15%	102	73
MW 224	3900-4200	SW 270	30-35%	111	75

Table 6.2 Number of plots, total number of trees sampled, and number of trees with full measurements.

Stand ID	# Plots	# Trees	# Full
B 287	15	119	40
LW 7	20	161	39
LW 18	20	137	40
LW 37	15	119	42
LW 452	15	120	37
MW 224	20	161	46

Table 6.3 Trees per acre: total and by species.

	Trees per Acre			
Stand ID	Total	NF	DF	OT
B 287	570.9	247.2	154.3	169.3
LW 7	341.9	283.3	37.3	21.3
LW 18	155.7	132.0	19.6	4.1
LW 37	271.2	200.4	39.7	31.0
LW 452	299.3	183.4	31.5	84.3
MW 224	457.5	356.9	39.1	61.5

Table 6.4 Basal area per acre: total and by species.

	Basal Area per Acre			
Stand ID	Total	NF	DF	OT
B 287	317.3	152.0	98.7	66.7
LW 7	321.8	247.8	52.0	22.0
LW 18	274.0	242.0	28.0	4.0
LW 37	317.3	240.0	42.7	34.7
LW 452	320.0	208.0	50.7	61.3
MW 224	321.8	226.0	64.0	31.8

Table 6.5 Quadratic mean diameter (inches): all species and by species.

	Quadratic Mean Diameter			
Stand ID	**All Species**	**NF**	**DF**	**OT**
B 287	10.1	10.6	10.8	8.5
LW 7	13.1	12.7	16.0	13.8
LW 18	18.0	18.3	16.2	13.4
LW 37	14.6	14.8	14.0	14.2
LW 452	14.0	14.4	17.2	11.6
MW 224	11.4	10.8	17.3	9.7

Table 6.6 Mean height of 40 largest trees and mean height of all trees.

Stand	HT 40	Mean HT
B287	77	65
LW7	94	83
LW18	109	103
LW37	102	91
LW452	93	84
MW224	100	81

Table 6.7. Weighted (by individual tree basal area) mean live crown ratio (%): all species and by species.

	Weighted Mean Live Crown Ratio			
Stand ID	**All Species**	**NF**	**DF**	**OT**
B287	33	29	30	39
LW 7	36	30	45	50
LW 18	40	40	37	42
LW 37	37	32	44	41
LW 452	30	31	46	23
MW 224	34	28	39	45

Table 6.8 Reineke's stand density index (Reineke 1933) and plant association (Marsh et al. 1987).

Stand ID	SDI	Plant Assoc.
B 287	580	ABAM/CLUN
LW 7	528	ABAM/CLUN
LW 18	401	ABAM/CLUN
LW 37	497	ABAM/CLUN
LW 452	513	ABGR/SYMPH
MW 224	564	TSME/XETE

The number of trees per acre by species in each diameter class for each stand are depicted in figure 6.1.

Figure 6.1 Number of trees per acre per diameter class by species (a) stand B287, (b) stand LW7, (c) stand LW18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)

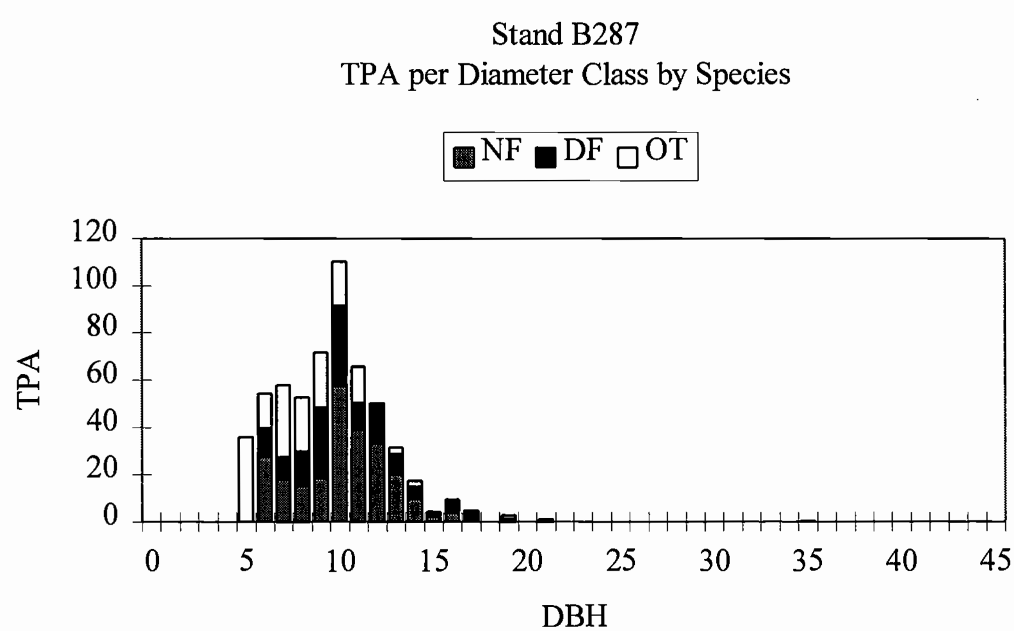
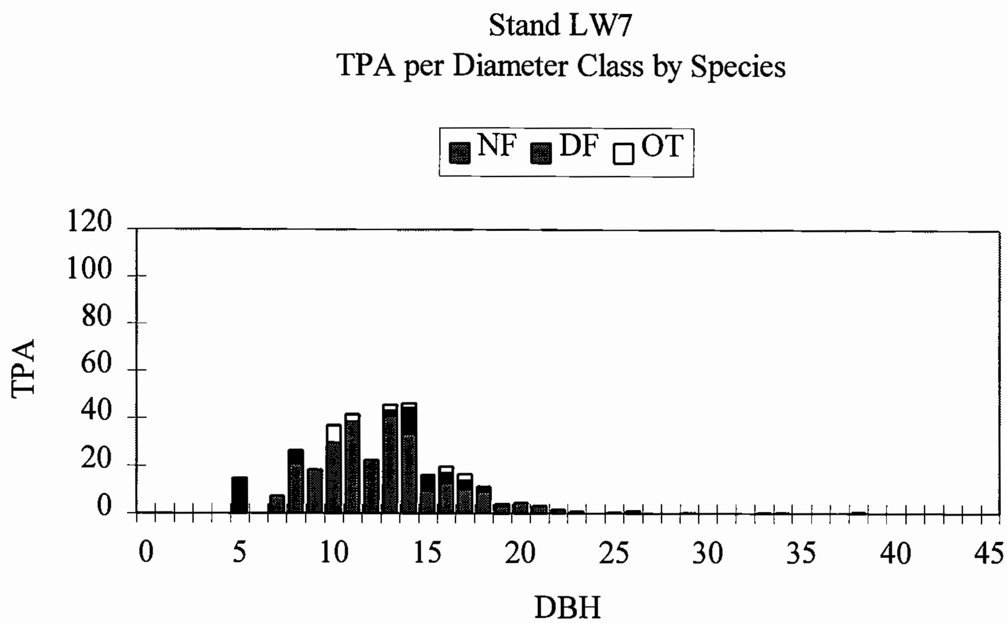


Figure 6.1 (Continued)

(b)



(c)

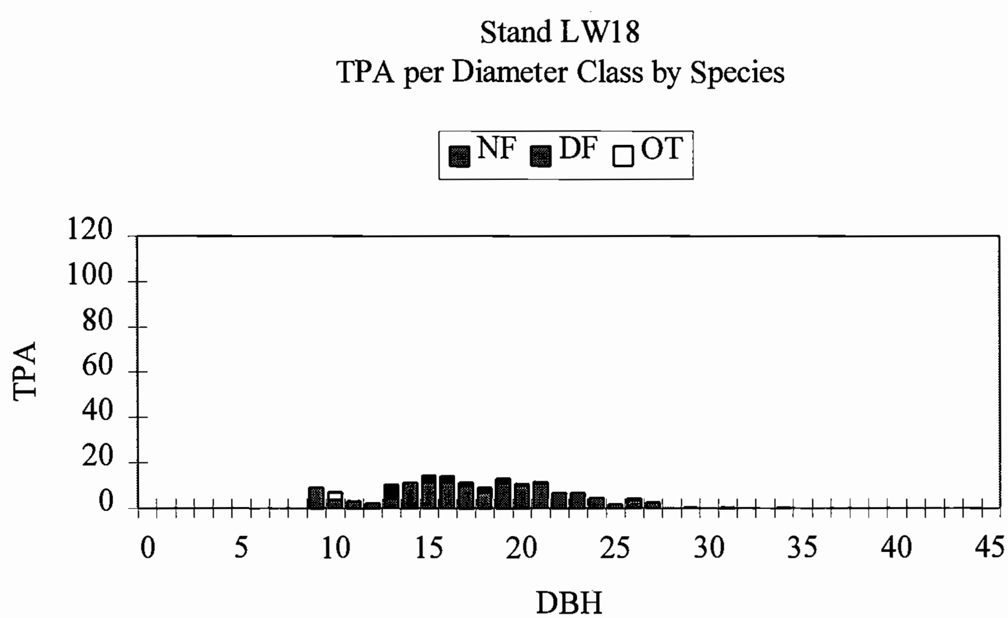
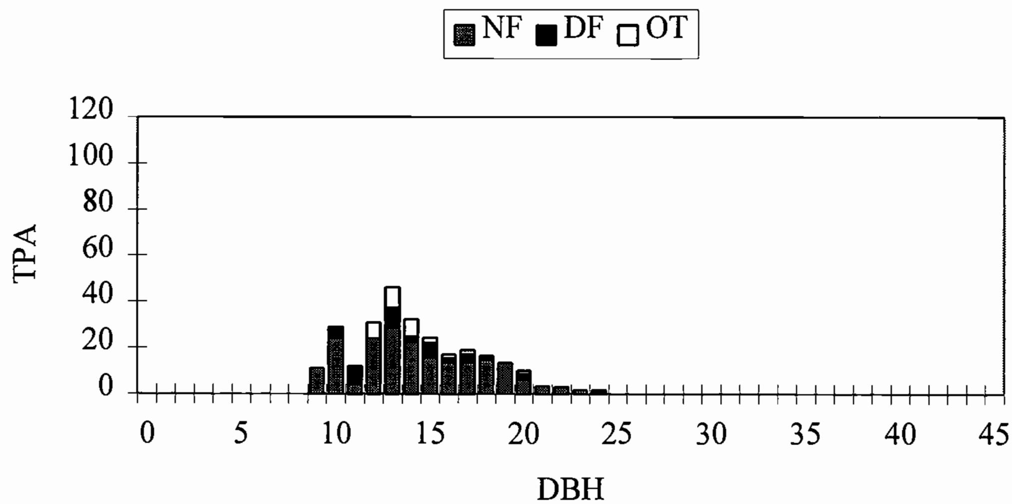


Figure 6.1 (Continued)

(d)

Stand LW37
TPA per Diameter Class by Species



(e)

Stand LW452
TPA per Diameter Class by Species

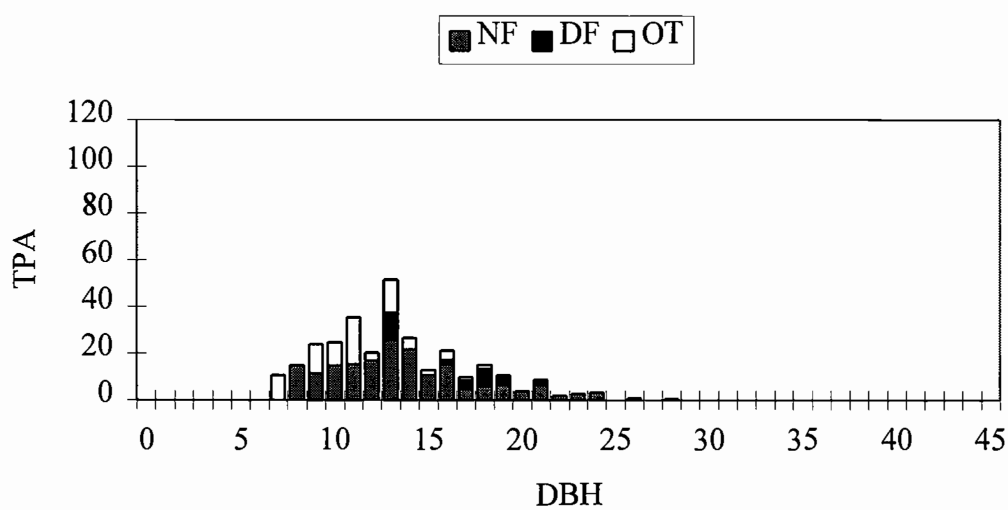
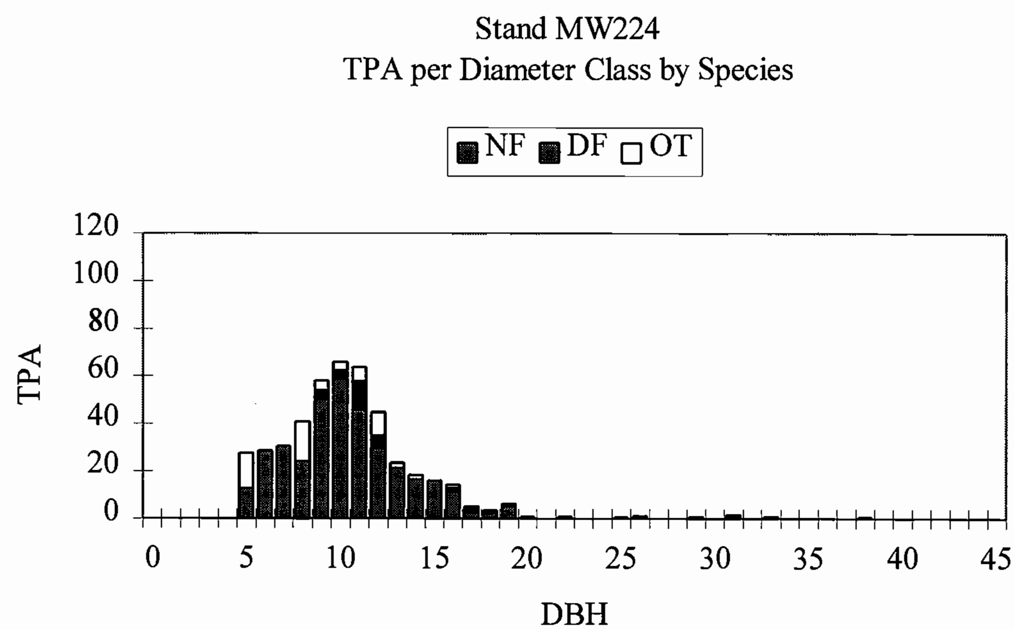


Figure 6.1 (Continued)

(f)



6.2 Effects of Thinning on Stand Volume

See table 6.9 for names and definitions of thinning regimes.

Table 6.9 Names and definitions of thinning regimes.

Name	Regime
C	Unthinned
1	Thin from below (low) to .25 MAX SDI
2	Thin from below (low) to .35 MAX SDI
3	Thin from below (low) to .45 MAX SDI
4	Thin from below (low)to .55 MAX SDI
5	Thin proportionally to .25 MAX SDI
6	Thin proportionally to .35 MAX SDI
7	Thin proportionally to .45 MAX SDI
8	Thin proportionally to .55 MAX SDI

When thinned to .25 MAX SDI, the total gross board foot volumes per acre in all stands 50 years after treatment were less than that of the unthinned stand. See figure 6.2 for total gross board foot volumes per acre by regime and by stand, 50 years after thinning. The total volume includes the volume removed during thinning at year 0. When thinned from below (low) to .25 MAX SDI, stand volumes were 78.4 percent to 88.0 percent of the unthinned stand volume. See table 6.10 for the percent volume of the unthinned stand. When thinned proportionally to .25 MAX SDI, stand volumes were 78.9 percent to 91.1 percent of the unthinned stand volume. Refer to pages 88 - 99 in the Appendix for a complete data set of stand volumes over time.

Figure 6.2 Gross board foot volume per acre 50 years after treatment (a) stand B287, (b) stand LW7, (c) stand LW18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)

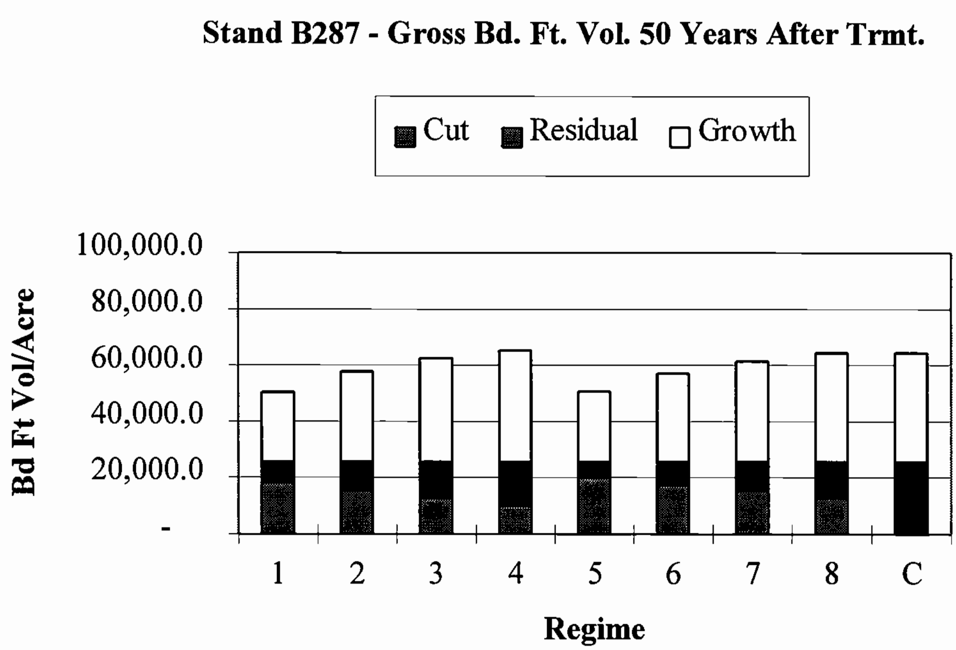
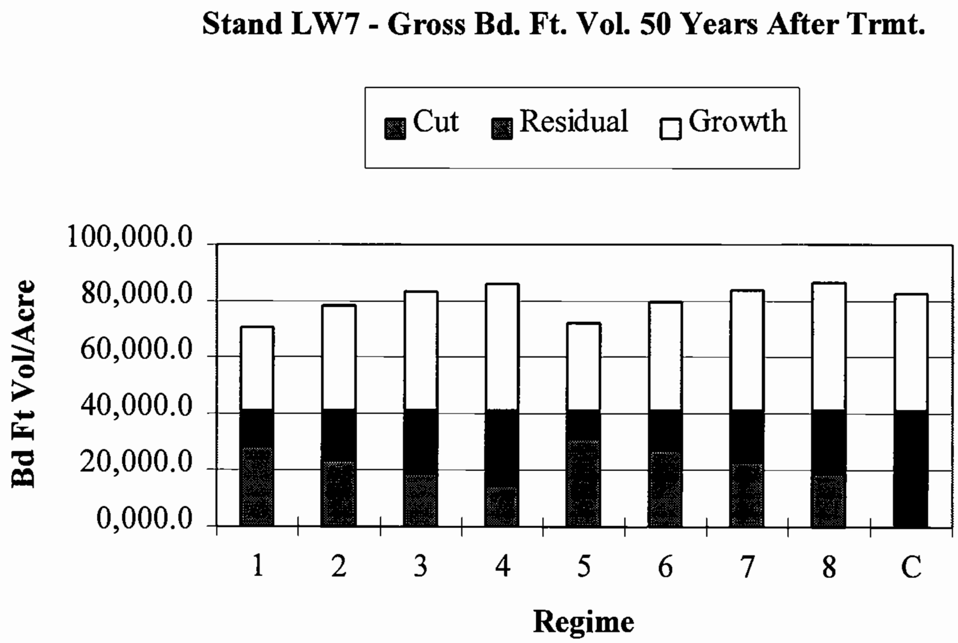


Figure 6.2 (Continued)

(b)



(c)

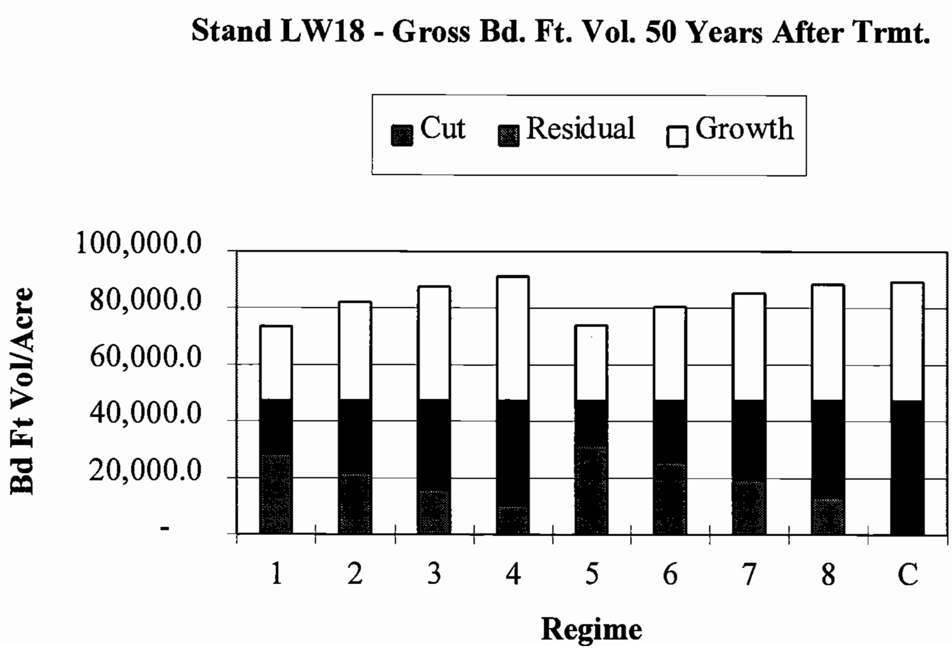
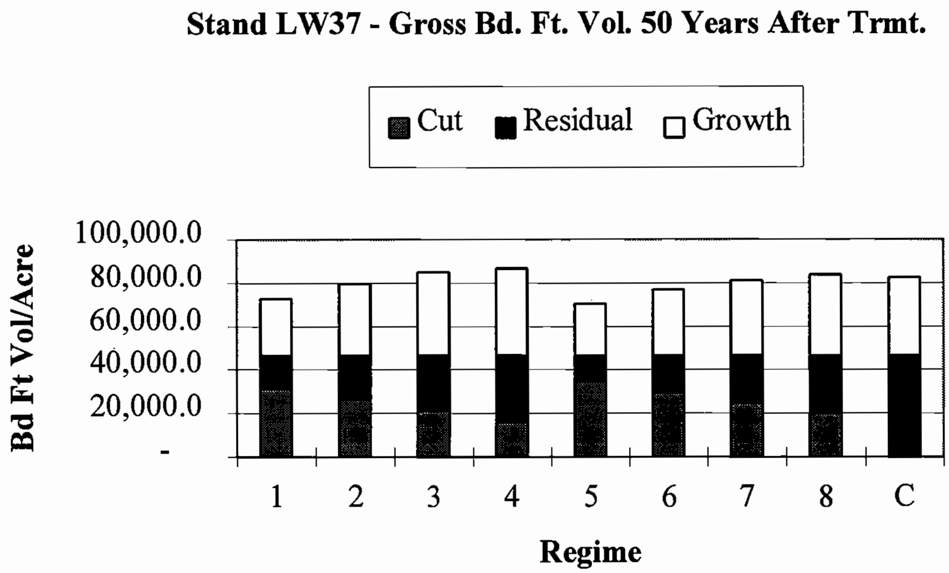


Figure 6.2 (Continued)

(d)



(e)

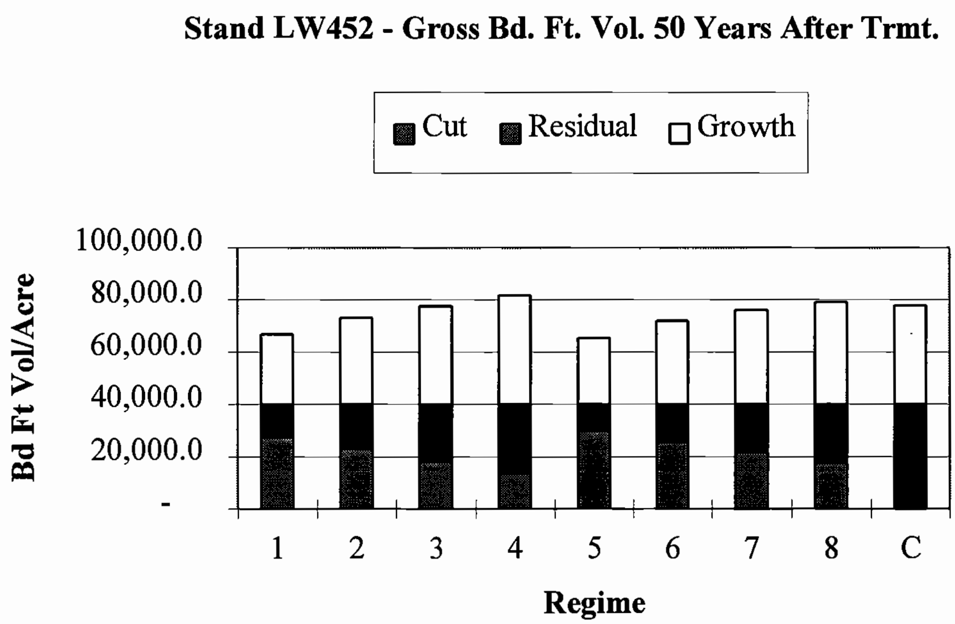


Figure 6.2 (Continued)

(f)

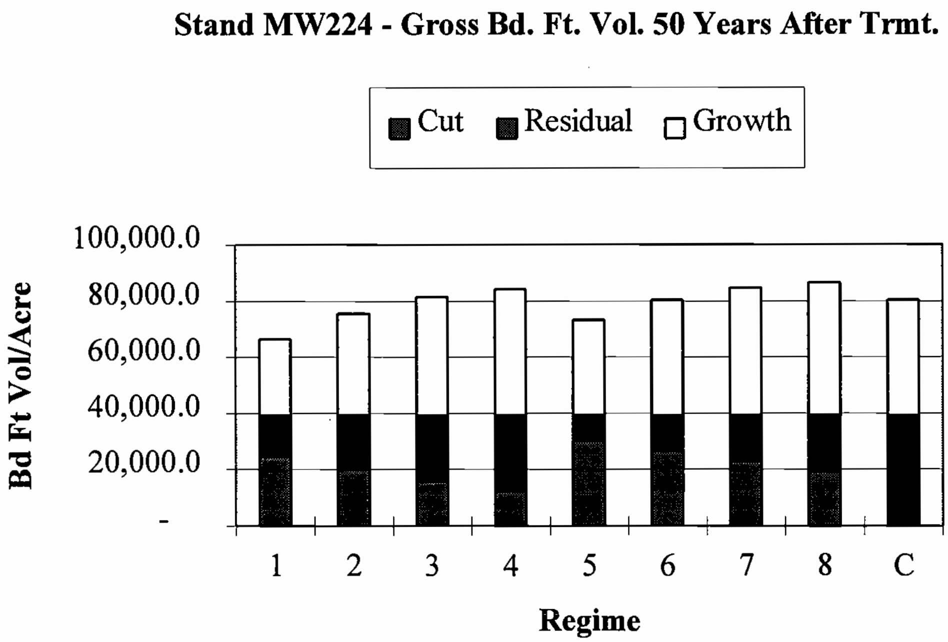


Table 6.10 Gross board foot volume per acre 50 years after treatment, percent of unthinned stand.

Regime	B287	LW7	LW18	LW37	LW452	MW224
1	78.4%	85.2%	82.2%	88.0%	85.7%	82.8%
2	89.6%	94.7%	91.8%	96.3%	93.9%	94.2%
3	97.4%	100.7%	97.8%	102.9%	99.7%	101.5%
4	101.6%	103.9%	101.9%	104.8%	104.9%	104.9%
5	78.9%	87.2%	82.8%	85.3%	83.9%	91.1%
6	88.8%	96.2%	90.1%	93.2%	92.4%	99.9%
7	95.5%	101.4%	95.5%	98.2%	97.9%	105.4%
8	100.1%	104.7%	98.9%	101.2%	101.5%	107.7%
C	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

When thinned to .35 MAX SDI, the total stand volumes, 50 years after thinning, were less than that of the unthinned stand. When thinned from below (low), stand volumes were 89.6 percent to 96.3 percent of the unthinned stand volume. When thinned proportionally, stand volumes were 88.8 percent to 99.9 percent of the unthinned stand.

When thinned from below (low) to .45 MAX SDI, 50 years after thinning, 3 stands had less volume and 3 stands had more volume than the unthinned stand. When thinned from below (low), stand volumes ranged from 97.4 percent to 102.9 percent of the unthinned stand volume. When thinned proportionally, 4 stands had less volume and 2 stands had more volume than the unthinned stand. When thinned proportionally, volumes ranged from 95.5 percent to 105.4 percent of the unthinned stand volume.

When thinned to .55 MAX SDI, all but one regime in one stand (LW18 - Regime 8) had more volume than the unthinned stand. When thinned from below (low), stand volumes were 101.6 percent to 104.9 percent of the unthinned stand volume. When thinned proportionally, stand volumes were 98.9 percent to 107.7 percent of the unthinned stand volume.

Four out of the 6 stands produced the most volume as a result of low thinnings. Two of the stands produced the most volume when thinned proportionally.

The gross volume growth increment was calculated over each 10 year period for the 50 year period after thinning. While growth increment among treatments and stands varied, there were no major increases or decreases. Some stands showed an increase in growth increment followed by a decrease, while others showed an initial decrease followed by an increase. Some stands and some regimes were still showing an increase in stand volume growth increment after the 50 year growth period while others were decreasing. Refer to pages 88- 99 in the Appendix for complete board foot volume 10 year growth increment values for each stand and regime.

6.3 Effects of Thinning on the Forty Largest Trees per Acre

Fifty years after thinning little difference was found among thinning regimes and the unthinned regime in mean diameter at breast height, mean total height, and mean live crown ratio of the 40 largest trees in Stand LW7. See table 6.11 for figures for all regimes 50 years after thinning. Refer to pages 88 - 99 in the Appendix for figures at 10 year increments from 1995 to 2045. In regimes that were thinned from below (low) and the unthinned regime the greatest difference in mean DBH was 0.33 inches, in mean HT the greatest difference was less than 1 foot, and the greatest difference in mean LCR was 4.78 percent. Among regimes that were thinned proportionally the differences in mean DBH, mean HT, and mean LCR were minimal. Mean DBH varied by 0.5 inches, mean HT varied by less than 1 foot, and mean LCR varied by 2.45 percent.

Table 6.11 Mean DBH, mean HT, and mean LCR of the 40 largest trees per acre for stand LW7 50 years after thinning.

Regime	Mean DBH	Mean HT	Mean LCR
Control	30.34	140.10	54.48%
R-1	30.19	139.64	52.25%
R-2	30.40	140.04	55.88%
R-3	30.48	140.18	57.03%
R-4	30.52	140.25	56.45%
R-5	31.80	140.86	63.60%
R-6	31.63	140.62	63.45%
R-7	31.47	140.59	62.60%
R-8	31.30	140.73	61.15%

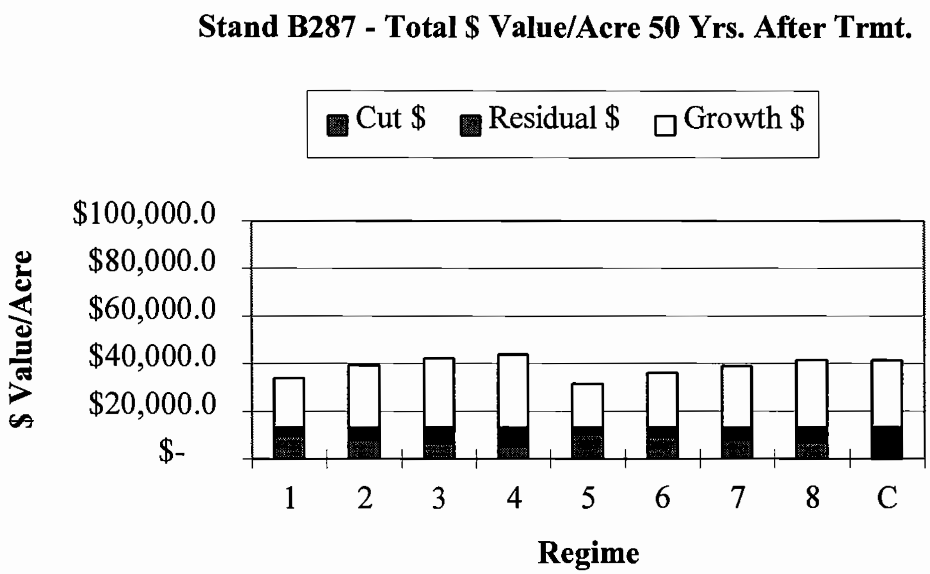
6.4 Effects of Thinning on Stand Value

<u>6.4.1 Stand Value</u>

When thinned to .25 and .35 MAX SDI, the total stand dollar values per acre 50 years after treatment were less than that of the unthinned stand. Total stand dollar value per acre includes the amount cut during thinning. No logging costs or present net worth evaluations are included. When thinned from below (low) to .25 and .35 MAX SDI, stand values ranged from 70 to 84 percent and 88 to 95 percent, respectively, of the unthinned stand value. See table 6.12 for percentages. When thinned proportionally to .25 and .35 MAX SDI, stand values ranged from 76 to 86 percent and 86 to 96 percent, respectively, of the unthinned stand value. Refer to pages 88 - 99 in the Appendix for a complete table of stand values. Refer to figure 6.3 for charts depicting stand value per acre 50 years after treatment.

Figure 6.3 Total dollar value per acre 50 years after treatment (a) stand B287, (b) stand LW7, (c) stand LW18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)



(b)

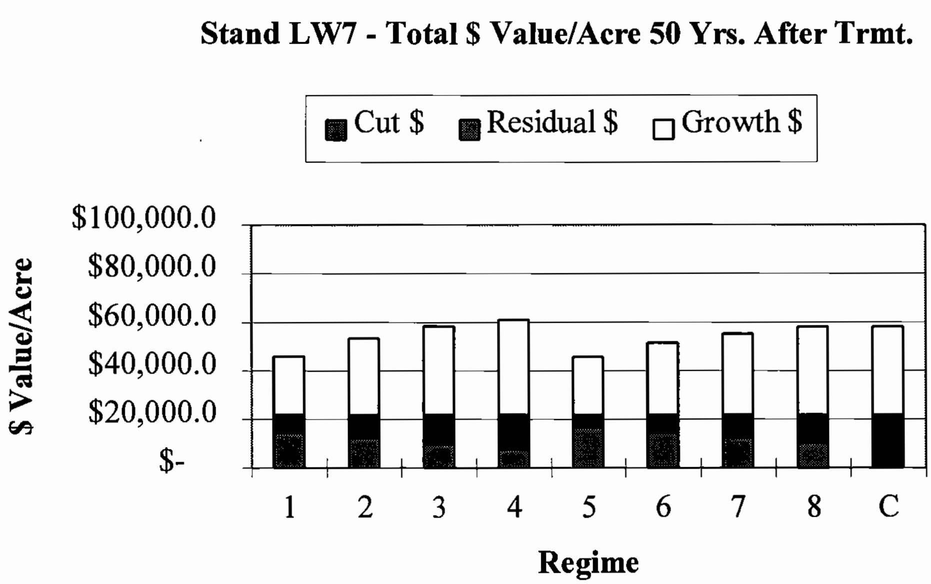
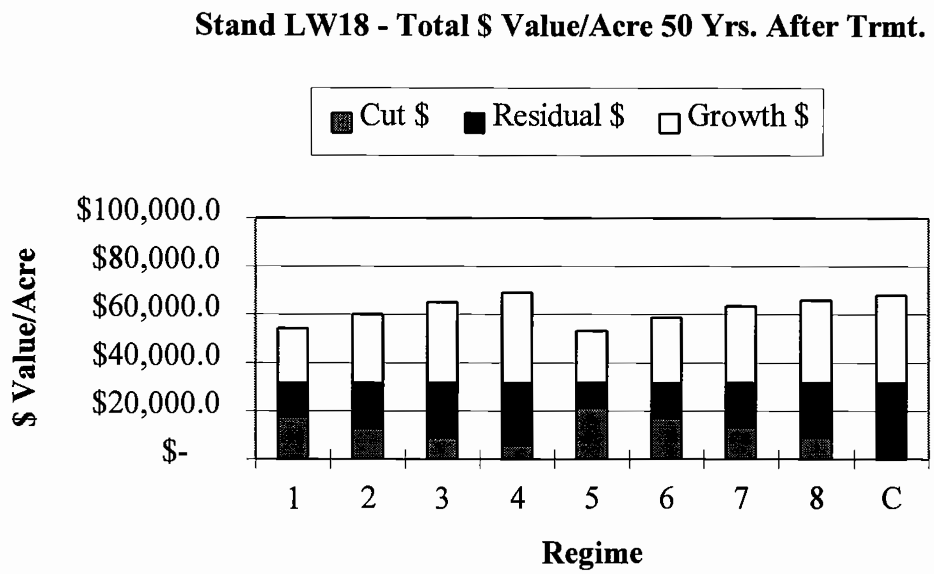


Figure 6.3 (Continued)

(c)



(d)

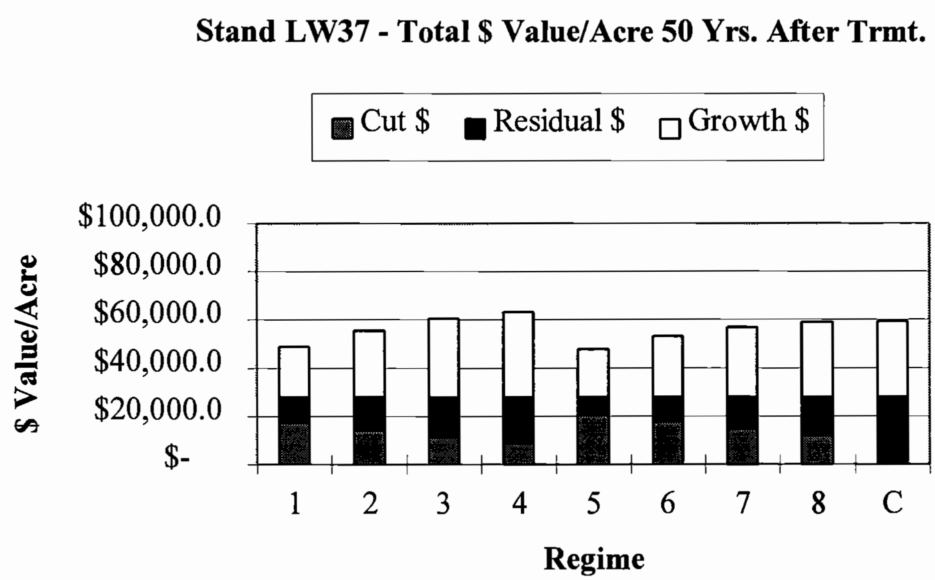
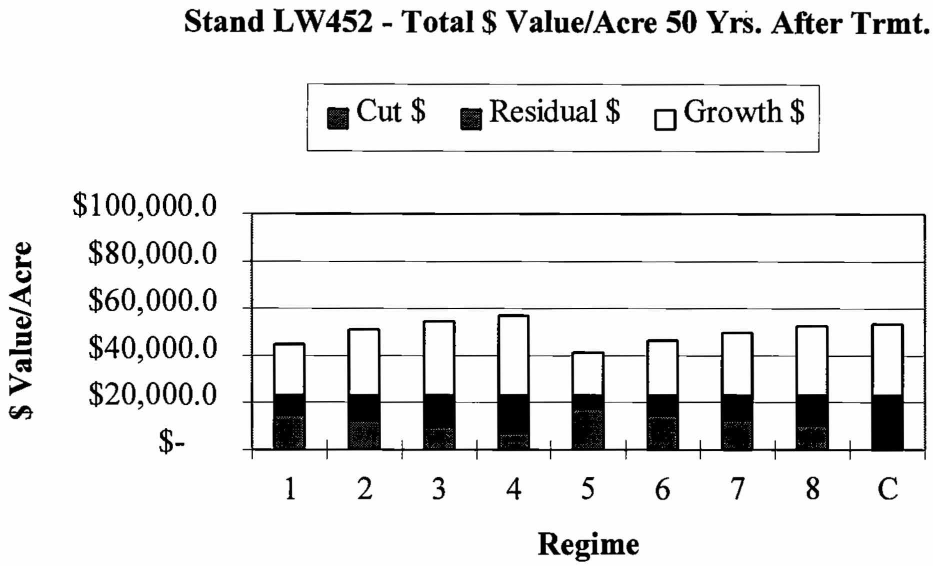


Figure 6.3 (Continued)

(e)



(f)

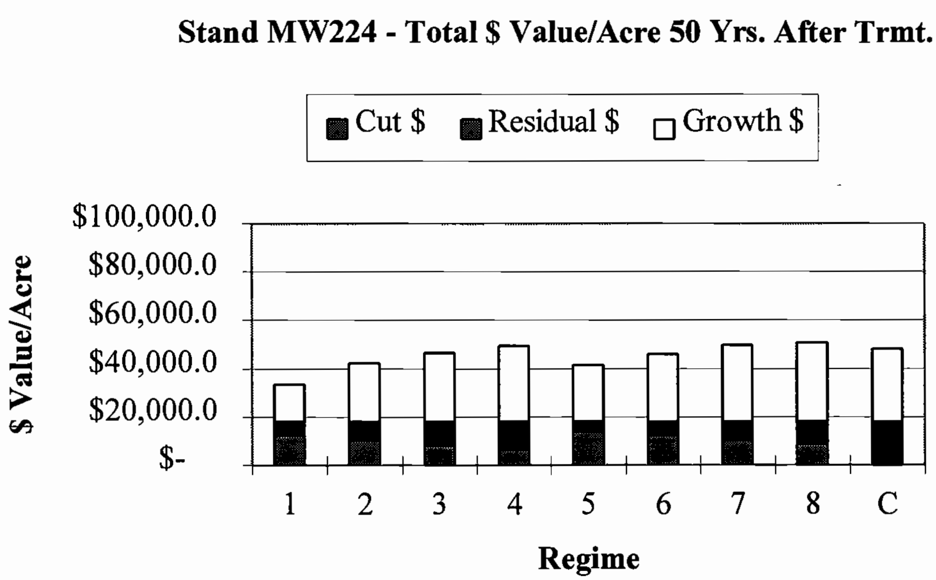


Table 6.12 Total stand value per acre 50 years after treatment, percent of unthinned stand.

Regime	B287	LW7	LW18	LW37	LW452	MW224
1	82.0%	79.3%	79.6%	82.4%	83.6%	69.5%
2	94.7%	91.6%	88.2%	93.4%	95.2%	88.0%
3	102.1%	100.5%	95.8%	102.2%	101.6%	96.9%
4	105.5%	104.8%	101.6%	106.6%	106.3%	102.5%
5	75.8%	78.8%	78.3%	80.5%	77.2%	86.2%
6	87.0%	88.7%	86.5%	89.6%	86.5%	95.8%
7	94.3%	95.0%	93.3%	95.6%	92.9%	103.1%
8	99.9%	99.9%	97.1%	99.2%	98.2%	105.3%
C	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

When thinned from below (low) to .45 MAX SDI, 2 stands had less value and 4 stands had more value than that of the unthinned stand. When thinned from below (low), stand values ranged from 95.8 percent to 102.2 percent of the unthinned stand value. When thinned proportionally, 5 stands had less value and one stand had more value when compared to the unthinned stand. When thinned proportionally, stand values ranged from 92.9 percent to 103.1 percent of the unthinned stand value.

When thinned from below (low) to .55 MAX SDI, all stand values were greater than that of the unthinned stand. Values ranged from 102.5 percent to 106.6 percent of the unthinned stand value. When thinned proportionally, 5 stands had less value and 1 stand had more value than that of the unthinned stand. When thinned proportionally, values ranged from 97.1 percent to 105.3 percent of the unthinned stand value.

The change in stand value over time in all scenarios is gradual without any extreme increases or decreases.

6.4.2 Present Net Worth Stand Value

For this analysis, a clearcut regime (CC) that took place at year 0 was included. At the 7 percent and 10 percent discount rates, with and without the 1 percent price increase, the clearcut regime for all stands had the highest present net worth. At the 4 percent discount rate, both with and without the 1 percent price increase some of the thinning regimes, usually Regime 5, had a slightly greater present net worth than the clearcut regime. Refer to pages 102 - 109 in the Appendix for complete values of the present net worth (PNW) analysis.

The unthinned stand regimes had the lowest PNW in all cases. Of the thinnings, those with the largest initial volume removal (thin to .25 MAX SDI) had the greatest PNW at three discount rates with no real price increase. With a 1 percent price increase and a 4 percent discount rate, half of the stands had the greatest PNW when thinned to .25 MAX SDI and half had the greatest PNW when thinned to .35 MAX SDI. The difference at these two thinning levels is minimal (0.1 to 3.8 percent). At the 7 percent and 10 percent discount rates, with a 1 % real price increase, the thinnings with the largest initial volume removal (thin to .25 MAX SDI) had the greatest PNW. The proportional thinnings generally had a higher PNW than low thinnings. With the exception of Stand B287 - Regime 2, Stand LW7 - Regime 2, MW224 - Regime 2, and MW224 - Regime 6 (4 percent discount rate, 1 percent price increase), the PNW decreased between regimes as the level of initial volume removal during thinning decreased. As the discount rate increases the PNW decreases for all stands and regimes. With a 1 percent price increase the PNW of all stands and regimes is greater than without the price increase. The difference becomes less significant at higher discount rates. At the highest discount rate the difference between the PNW with the price increase and the PNW without the price increase is negligible. Refer to figure 6.4 (a) - (f) for charts depicting the PNW of each regime.

Figure 6.4 Present net value of total net revenue per acre 50 years after treatment (a) stand B287, (b) stand LW7, (c) stand LW18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)

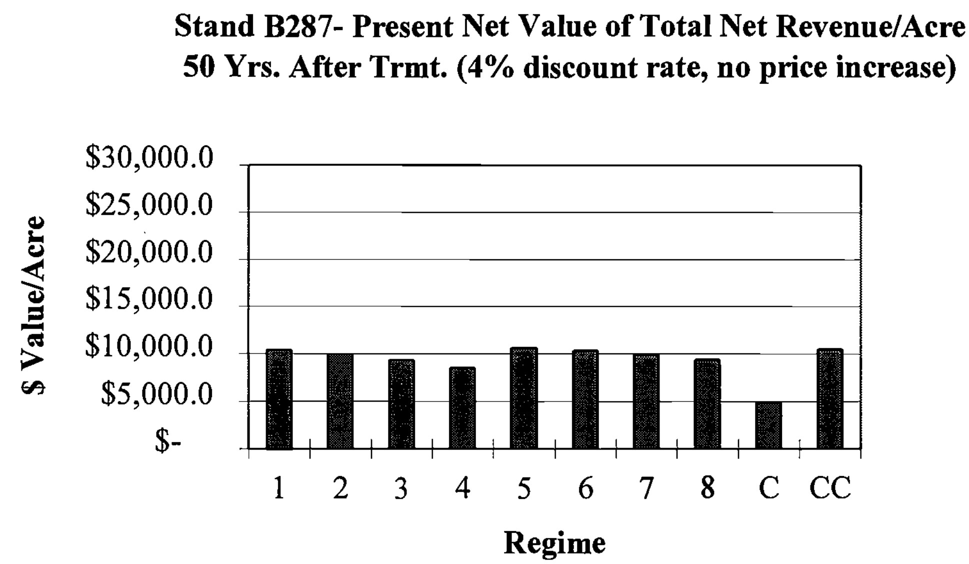
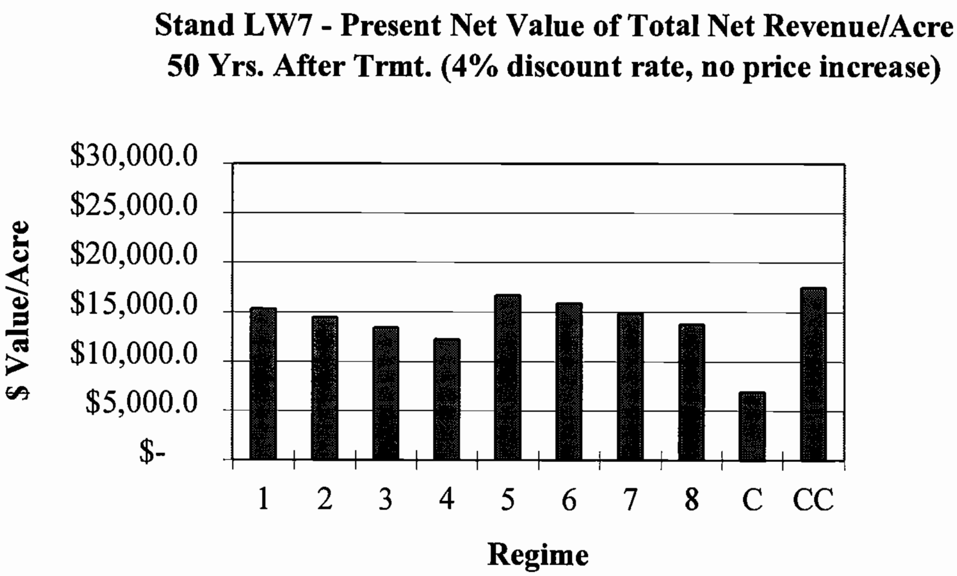


Figure 6.4 (Continued)

(b)



(c)

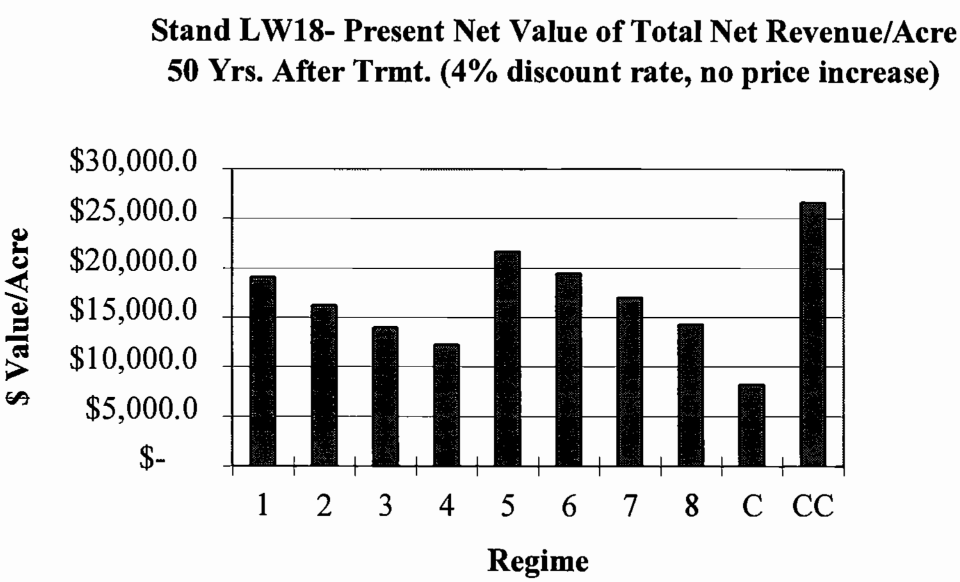
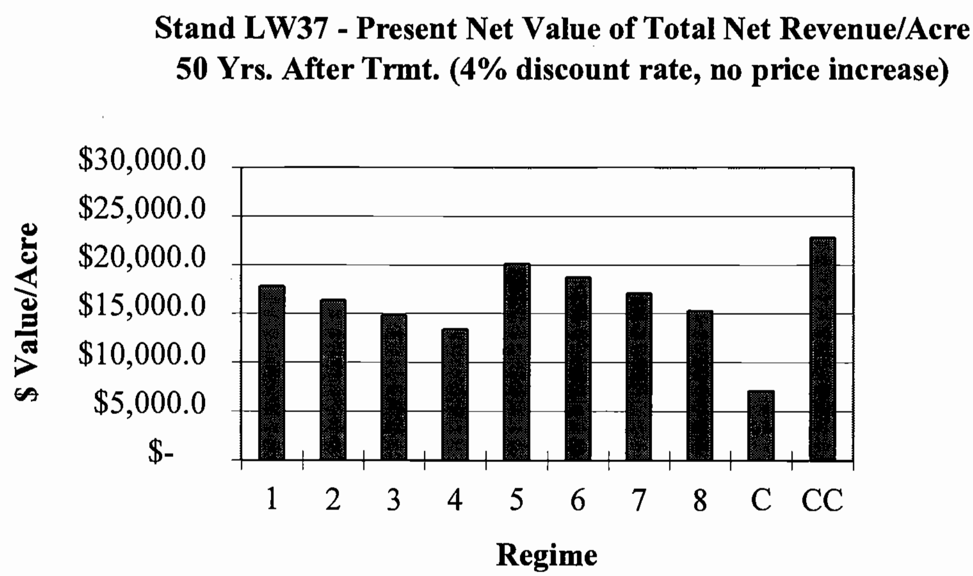


Figure 6.4 (Continued)

(d)



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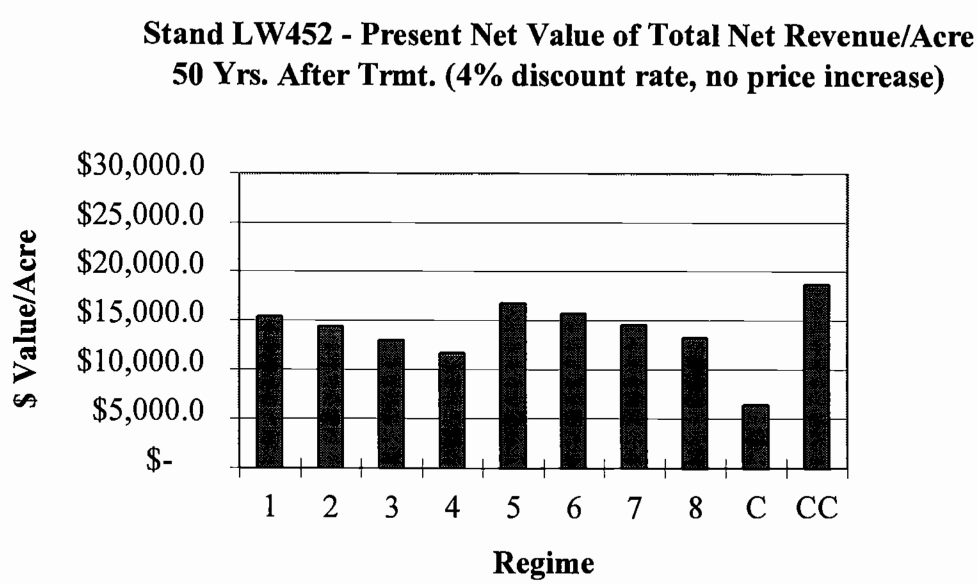
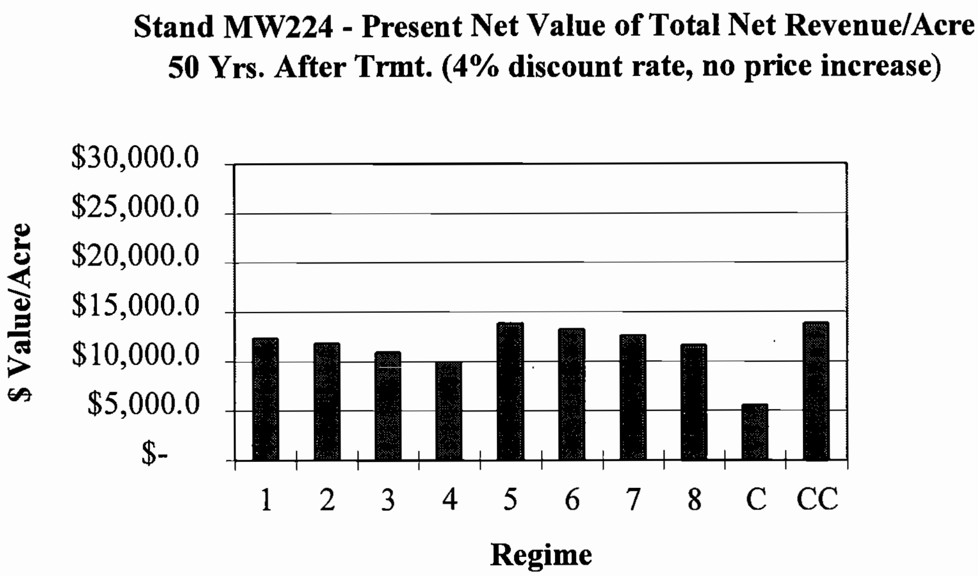


Figure 6.4 (Continued)

(f)



6.5 Logging Damage Sensitivity Analysis

6.5.1 Individual Tree Damage

The sensitivity analysis of varying levels of logging damage to residual trees resulted in decreases in stand value when compared to an undamaged stand. At 20 percent, 40 percent, and 60 percent levels of residual stand damage, gross board foot volume per acre, 50 years after thinning, decreased by 1.6 percent, 3.2 percent, and 4.8 percent, respectively, when compared to an undamaged stand. Decreases in stand value at the range of damage levels were the same across all thinning regimes including the unthinned stand. At the 20 percent damage level, stand value decreased 1.65 percent to

1.75 percent. At the 40 percent damage level stand value decreased 3.29 percent to 3.51 percent. At the 60 percent damage level stand value decreased 4.94 percent to 5.26 percent. Refer to page 110 in the Appendix for a table showing the volume and value loss, at each level of damage, for each regime.

6.5.2 Stand Level Damage

Volume losses were greater when the stand level decay loss equation was used to calculate board foot volume loss due to residual stand damage. At damage levels of 20 percent, 40 percent, and 60 percent, gross board foot volume per acre, 50 years after thinning, decreased by 8.7 percent, 14.4 percent, and 20.3 percent, respectively, when compared to an undamaged stand. At the 20 percent damage level, stand value decreased 8.95 percent to 9.54 percent, when compared to an undamaged stand. At the 40 percent damage level, stand value decreased 14.83 percent to 15.81 percent. At the 60 percent damage level, stand value decreased 20.85 percent to 22.22 percent. See page 111 in the Appendix for actual values regarding stand level damage.

6.6 Effects of Thinning on Log Small End Diameter Distribution

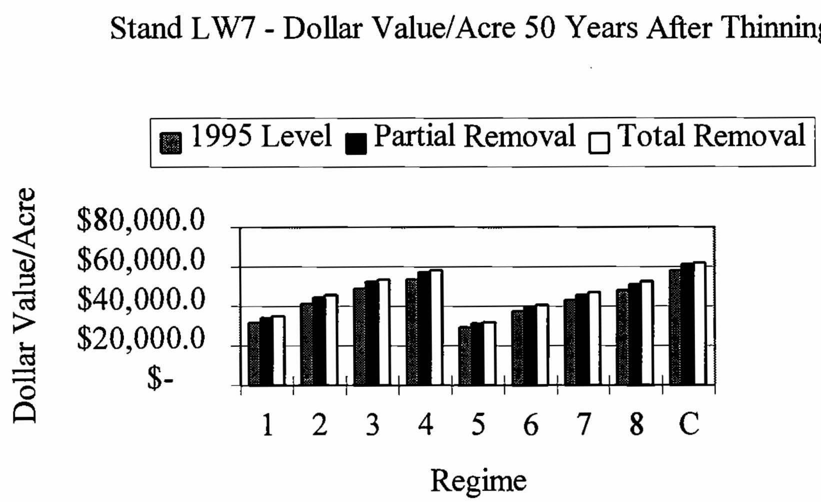
As expected, logs shift into larger diameter classes over time. Each 10 year increment shows movement of logs into larger diameter classes. The main difference between thinning regimes is found when comparing stands thinned from below (low) with stands thinned proportionally. Stands thinned from below (low) have fewer logs in smaller diameter classes and more logs in larger diameter classes, whereas, stands thinned proportionally have more logs in the smaller and mid-range diameter classes. Refer to pages 112 - 114 in the Appendix for a table with the number of logs per diameter class for each regime over time. See page 115 in the Appendix for charts depicting the distribution of log small end diameters.

When comparing the number of logs in the 6 to 10 inch log small end diameter classes at year 2045, all thinning regimes had fewer logs per acre in these classes than the unthinned stand. In the 12 inch to 20 inch log small end diameter classes, all thinning regimes resulted in fewer logs per acre than the unthinned stand. In the 22 inch to 30 inch log small end diameter classes the regimes thinned from below (low) had between 41 percent and 59 percent more logs per acre than the unthinned stand. All but one of the proportionally thinned regimes had 5 percent to 35 percent fewer logs per acre in the 22 inch to 30 inch log small end diameter classes when compared to the unthinned stand. Regime 8 (proportional thinning to .55 MAX SDI) produced 3 percent more logs in the large diameter classes compared to the unthinned stand.

6.7 Results of Branch Presence Analysis

Removing branches from the first log resulted in an increase in value 50 years after thinning and branch removal (cost of pruning not included). See page 116 in the Appendix for values per acre, 50 years after thinning. See figure 6.5 for a graph depicting value per acre, 50 years after thinning, for the three branch presence scenarios. Total branch removal in the first log increased dollar value per acre 9 percent to 11 percent for the thinned regimes and by 6 percent for the unthinned regime. Partial branch removal increased dollar value by 6 percent to 8 percent for the thinned regimes and by 5 percent for the unthinned regime.

Figure 6.5 Dollar value per acre 50 years after treatment for 3 branch scenarios.



The present net worth of the future value of the benefit gained from branch removal was calculated (cost of pruning not included). See page 116 in the Appendix for values. With a 4 percent discount rate and no real price increase total branch removal from the first log resulted in a present net worth gain of 383 dollars and to 643 dollars per acre across all regimes. Partial branch removal resulted in a present net worth gain of 277 dollars and to 510 dollars per acre across all regimes.

7.0 Discussion

7.1 Discussion of Initial Assumptions

Two initial assumptions were made before commencing research on thinning these stands. First, thinning would result in stands containing larger-diameter logs which are more valuable, and second, thinning would provide the opportunity to utilize trees that would otherwise be lost to mortality.

This analysis does not support either assumption. After a 50 year growth period larger-diameter, higher value logs were not found to be a result of thinning. The second assumption was not found to be true because significant mortality, due to suppression and insect related events, has already taken place in these stands. Mortality has occurred primarily in the Douglas-fir stand component. Due to the amount of time that has passed since insect damage occurred most of the affected stems are not salvageable.

Many of the thinning studies in the literature support the second assumption that one of the main advantages of thinning is the opportunity to capture future mortality (Reukema and Bruce 1977, Williamson 1982, Worthington 1966, Worthington and Staebler 1961). The thinning regimes do not capture enough future mortality to significantly increase total volumes when compared to the total volume of the unthinned regime, despite the fact the unthinned regimes had the greatest mortality over time. As noted above the conditions of these older noble fir stands affect the opportunity to capture future mortality.

7.2 Discussion of FVS

It is difficult to adopt a high degree of confidence in the performance of the WC variant of the FVS growth model because there are no actual long term data on growth of thinned older noble fir stands to use for model validation purposes. Comparisons of actual growth from WSIR CFI data and FVS model simulations allowed for some model adjustments to be made.

To evaluate the performance of the two types of thinning regimes (low and proportional) the outcomes of two thinning regimes and an unthinned regime were studied. The thinning regimes included a low thinning to 100 square feet of basal area/acre and a proportional thinning to 100 square feet of basal area/acre. Fifteen trees across the range of diameters were selected for comparison between regimes. When comparing the average diameter, height, and live crown ratio measurements of the same 15 individual trees between the proportional thinning and the low thinning, the differences were minimal after 50 years growth. Fifty years after thinning, the 15 trees in the proportional regime were, on average, only slightly larger than the 15 trees in low thinning regime. The 15 trees in the proportional thinning were, on average, greater by 1.58 inches in DBH (5.67%), 1.59 feet in height (1.17%), and 12.73 percent in live crown ratio. When the low thinning regime was compared to the unthinned regime the 15 trees in the unthinned regime, on average, had greater growth. The 15 trees in the unthinned regime were, on average, greater by 0.26 inches in DBH (0.95%), 0.93 feet in height (0.69%), and 6.33 percent live crown ratio. This outcome is contrary to what is expected. The literature shows that thinning may enhance diameter growth. Oliver

(1988) found that thinned regimes had greater diameter growth than unthinned regimes in 100-year-old true fir stands. Worthington (1966) also reported an increase in diameter growth in thinned regimes over unthinned regimes in 60-year-old Douglas-fir stands.

The results of thinning and growth on individual tree diameter increment between the low thinning regime and the unthinned regime prompts a question as to the ability of FVS to accurately model low thinning regime response in these 65- to 85- year-old stands. The results of the simulated thinning regimes need to be viewed with caution as they are computer modeled outcomes and not actual stand results.

7.3 Discussion of LOGTABLE Program

7.3.1 Gross Board Foot Volume

Gross board foot volumes calculated using the LOGTABLE program are different from gross board foot volumes calculated using FVS because different equations and log lengths are used. The FVS model uses 32 foot log lengths while LOGTABLE uses 40 foot log lengths and FVS uses different equations for taper, volume, and bark thickness. The LOGTABLE model predicts a lower volume than the FVS model.

7.3.2 Optimal Bucking

Optimal bucking has been shown to increase value compared to bucking fixed log lengths (Olsen et al. 1991, Sessions 1988). Optimal bucking was not used in this analysis for two reasons. First, it would have called for a more complex analysis program, and second, the Confederated Tribes of the Warm Spring Indian Reservation does not currently practice optimal bucking. If optimal bucking were used in these commercial thinning scenarios the outcome would likely be an increase in value across all regimes.

7.3.3 Old-growth Douglas-fir

To determine whether or not excluding a dollar value for old-growth Douglas-fir existent in the stands affected the results of this study, total stand value with a value for old-growth Douglas-fir was calculated and compared to the total stand value without a value for old-growth Douglas-fir. An arbitrary value of $700/MBF for old-growth Douglas-fir was used. The new value was calculated for the various thinning regimes for the period 50 years after treatment.

Excluding the old-growth value for Douglas-fir from this analysis did not affect the differences between the outcomes of the thinning regimes for the 5 stands with minimal amounts of old-growth Douglas-fir. The stand with a significant amount of old-growth Douglas-fir was the only one affected. This makes sense because of the large amount of old-growth Douglas-fir volume present in this stand that didn't have an associated value in the initial analysis. Adding the old-growth value to this stand resulted in the effects of thinning being more valuable for low thinnings and slightly less valuable for proportional thinnings when compared to analyzing the regimes without a value for old-growth Douglas-fir. This is due to the nature of proportional thinning which removes trees across the range of diameters, removing a portion of the old growth. Low thinnings retain the old-growth, larger, more valuable trees. Retention of the larger trees results in a higher value stand over time.

7.4 Discussion on Effects of Thinning on Stand Volume and Stand Value

Light thinnings result in a slight increase in total gross board foot volume 50 years after thinning. Heavy thinnings result in a decrease in total gross board foot volume 50 years after thinning. It is difficult to make a direct comparison of these results to thinning studies found in the literature. This study focused on total gross volume and total gross value 50 years after thinning while other studies present gross periodic annual volume increment analysis (Cochran and Oliver 1988), percent of normal net growth (Williamson 1982), and gross volume growth increment (Worthington 1966). Total gross volume and total gross value 50 years after thinning include the volume and value removed during thinning.

The trend between the type of thinning regime (proportional vs. low), the level of thinning (light to heavy volume removal), and the resulting total volume is not the same between stands. When low thinning regimes are analyzed separately from proportional thinnings, and the control is left out, the increase in volume and value is congruent. The regime with the most total volume has the highest value and the regime with the least total volume has the lowest value.

When the unthinned regime is included in the comparison of regimes, the effects of thinning are obscured. Volume and value are not always congruent. The regime with the greatest volume does not always have the greatest value. The control always has more volume than the two heaviest thinning regimes. After this there is no discernible pattern among stands as to where the unthinned regime ranks in terms of volume and value.

Initial stand conditions influence the effects of thinning. When lightly thinned from below (low) , 5 out of 6 stands show an increase in volume over 50 years, with a similar increase in value. This indicates that the increase in stand volume is the major factor responsible for the increase in stand value. One stand, B287, shows a larger increase in value than in volume. This indicates that the stand has shifted in value not only as the result of volume increase, but also as the result of capturing higher value log grades. Stand B287, had the smallest initial QMD and the lowest site index. It appears that this stand had a greater opportunity through thinning response to shift into higher value logs, whereas the other stands may have already reached a point where significant increases into higher value logs had already occurred.

When stands were lightly thinned, proportionally, 5 out of 6 stands did not show an increase in value when compared to the control. Four of these stands had only a slight increase in volume, up to 1.5 percent, when compared to the control. One of the stands, LW7, produced 4.7 percent more volume than the control. One stand, MW224, showed a slight increase in stand value and stand volume when thinned proportionally. This response to thinning may be explained by the characteristics of the stand. When compared to the other stands, MW224 had a much larger amount of residual old-growth Douglas-fir.

In conclusion, it appears that thinning proportionally does not increase stand value or volume enough to merit the application of this type of regime. Light thinning from below (low) results in a slight increase in stand volume and value. Increases in value compared to the unthinned regime are in most cases a result of increases in stand volume. The average value per MBF does increase as a result of thinning. However, this increase does not outweigh the influence of stand volume when determining stand value, except in Stand B287, where initial starting conditions provide room for a noticeable shift through response to thinning into higher value logs. There were no studies found in the literature review that focused on stand value, therefore no comparisons can be made with the results of this portion of the analysis

When deciding whether or not to thin a stand, each stand should be looked at on an individual basis for its potential response to thinning both in terms of volume and shifts in value.

The small difference in mean values between the low thinning regimes and proportional thinning regimes is not enough to determine whether one method of thinning is preferable to the other in the context of this study. The questionable performance of the FVS model when simulating low thinning regimes also makes it difficult to have confidence in comparisons between low thinning regimes and proportional thinning regimes. In the literature, a few studies have included both low thinnings and proportional thinnings (Williamson and Price 1971, Williamson 1982). The authors don't elaborate on the differences and responses between the two types of thinnings.

7.5 Discussion of Effects of Thinning on Forty Largest Trees Per Acre

When looking at the change in DBH, HT, and LCR of the 40 largest trees per acre in stand LW7, differences are minimal between thinning regimes and the unthinned regime. Height growth is not expected to differ significantly among regimes. Oliver (1988) found that height growth of crop trees was not significantly influenced by stand density. The results of diameter growth increment in this study are contrary to some of the findings in the literature. The literature shows that diameter growth can be enhanced when additional growing space is provided through thinning. Oliver (1988) reported that thinning 100-year-old true fir stands enhanced diameter growth. Williamson (1982) found that thinning 110-year-old Douglas-fir resulted in an increase in individual tree volume growth compared to unthinned regimes. Worthington (1966) also found an increase in diameter growth as a result of thinning 60-year-old Douglas-fir stands.

The lack of growth response to thinning may be a reflection of the performance of the FVS growth model. Wykoff (1982) reports that diameter increment predictions are influenced by stand density and individual tree dominance. The results indicate that density plays a lesser role in diameter increment predictions than individual tree dominance.

7.6 Discussion of the Effects of Thinning on Present Net Worth

Calculating present net worth favors harvesting regimes that bring in the most money at the earliest time. A clearcut regime was included in this analysis to illustrate this point.

The discount rates and level of price increase used in this type of analysis play a major role in determining which regime has the greatest PNW. As discount rates increase, the PNW over time decreases. As prices increase over time, the PNW also increases. If prices are increasing, regimes removing less volume at present and more volume in the future (at the time of final harvest) result in greater PNW. The shift of regimes with the greatest PNW, seen at the 4 percent discount rate level, is due to the 1 percent real price increase. When the price increase scenario was reduced to a real price increase of 0.5 percent, the .25 MAX SDI thinning level had the greatest PNW, as was the case with no price increase. If prices stay the same, or increase only slightly, then regimes removing the most volume at present provide economic advantage.

7.7 Discussion on Damage Sensitivity Analysis

The stand level decay equation resulted in a greater volume loss than the individual tree decay equation. The variables affecting the volume loss associated with a logging wound include the age of the wound, the age of the stand, the size and depth of the wound, and the species of the tree. The most significant of these variable is the age of the stand. It is known that as the age of the stand increases, decay increases. Therefore, the longer the stand is held after thinning, the greater the likelihood of decay (Greg Filip, personal communication, 1996).

When thinning only slightly increases stand value, a small amount of value loss due to residual tree damage negates this increase.

In this analysis, an average price per board foot is used for each stand when calculating the value of the volume loss. This is a conservative figure since most logging damage occurs in the first log of the tree and this is the most valuable log of the tree. Therefore, the value loss may likely be higher than estimated.

Damage may also have consequences extending beyond volume deduction. Damage could result in grade or sort reduction. This type of value reduction is difficult to calculate as it is a judgment call made by log brokers and customers. It is difficult to quantify how log damage/defect is viewed on the export market. Export log buyer, Chris Beckett, (Pacific Lumber and Shipping, Portland, Oregon, personal communication, 1996) said that a small amount of log damage/defect would be acceptable for a group of logs, but if a large number of the logs coming into the export log yard had damage/defect they would be put in a lesser value sort or may not qualify for the export market at all. The export market sorts are particularly sensitive to visual evaluation of log damage/defect.

Decay may not be the only or most important issue when determining volume loss as a result of damage during thinning to residual trees. Other defects that result from scarring such as pitch ring, stain, etc. may also result in significant amounts of volume deduction. Past studies on volume loss from logging damage have concentrated on decay. When other defects are counted the total loss is may be much greater.

Damage to residual trees may also affect the tree's ability to grow, survive, and withstand insect and disease attack. Increased mortality, if the volume goes uncaptured, will affect the total value of the thinned stand. Results from the work that Sullivan and

Filip (in progress) are doing on noble fir on the WSIR will provide much needed information.

In the noble fir stands in this study it is difficult to predict decay loss. The equations used were for related species. Losses may be greater than the values calculated in this analysis. The lack of information available on decay loss resulting from logging damage to noble fir trees, reduces this analysis to conjecture. The best approach to reducing potential decay loss is to avoid injury to residual trees.

7.8 Discussion of Branch Retention Analysis

The increase in dollar value per acre that resulted from simulating the removal of branches from the first log is minor. After pruning costs there would be little or no gain accrued from removing branches. This analysis did illustrate that branch frequency in these stands is not a key characteristic in determining log value. Log size (diameter) is the key determinant in this analysis. If these logs met the ring count requirements of higher value sorts the presence of branches may be much more critical.

7.9 Discussion of Log Market and Sorts

In the 6 stands studied, the components of grading that most affect grade and sort allocations are small end log diameter, log length, number of rings per inch, presence and frequency of knots, dead branches, and live limbs. Other grading criteria which were not accounted for in this analysis include defect in the form of decay, sweep, pistol butt, and frost cracks.

The criteria defining log sort allocation for the export market are subjective and difficult to quantify. For example, "old growth characteristics" are at present very desirable in the export noble fir market. Old growth characteristics, including deeply, fissured bark and closely spaced, uniform growth rings throughout the entire diameter place logs into high value sorts. A log with tight ring count in the outer half of the diameter but not in the center would not meet the criteria for the highest value export sorts. In discussion with export log buyers, it was noted that very little or none of the second-growth noble falls into this high value export sort because of shortfalls in meeting ring count requirement and desired bark characteristics. Exactly how long would it take these second growth noble fir to develop thick, fissured bark is unknown. If this were to take place, the ring count would still be more erratic and not as tight as today's old-growth noble fir. Based on the information gained from the export log buyers, it becomes apparent that as long as the purchaser's valuation remains the same, these noble fir stands, thinned or unthinned, will not move into the high value sorts over the next 50 years.

It is reasonable to expect that, as in the past, specifications for what is acceptable and desirable will change. It is difficult to predict what the log market will be like in 50 years.

7.10 Discussion of Stand History

The fact that these second-growth noble fir logs don't have the ring count characteristics necessary to meet the requirements of the high value export sorts raises an interesting question. That question is “why are these second-growth stands producing different growth characteristics than the previous old-growth noble fir stands”. It is probable that both stand types were established by stand replacement fire events. Old-growth logs have tight, even ring count throughout the entire diameter whereas, the second-growth logs have varying ring count. The exact cause of this is unknown. Perhaps the difference in ring count characteristics could be explained by variation in stand establishment, stand structure, species composition, or climate.

7.11 Future Research Needs

Future research on actual thinning regimes of noble fir stands, similar to those in this study, would be helpful in further understanding the results of this study. Information on mortality, diameter growth, height growth, crown growth, branch occlusion, and decay would provide a base of actual data for comparison with the growth predictions and assumptions made in this analysis. Noble fir stands currently being thinned on the WSIR could provide an immediate source of information. Information on logs harvested such as board foot volume, amount of defect, and log grades and sorts would be useful in determining the validity of some of the assumptions and outcomes made in this exercise.

Further research on logging damage and resulting decay of individual trees is very important in understanding the role that damage plays.

7.12 Other Relevant Issues

There are many issues besides volume and value that need to be carefully examined when considering thinning as a silvicultural management option. The effects of thinning on windthrow occurrence, soil compaction, sunscald, and fire hazard need to be considered. The desired future condition and structure of the stand needs to be taken into account. The implications of thinning on stand health issues such as insects and disease must be recognized.

As discussed in the introduction, interest in thinning is backed by the desire to generate higher value trees, to improve stand vigor, and to provide an immediate sources of wood supply. While this study shows that thinning only slightly increases stand value the other reasons for thinning are still valid. The decision to thin this type of noble fir dominated stand depends on the desired future stand condition and economic goals. If the goal is to solely increase stand value by thinning, thinning would not be recommended. If the goal is to both harvest for an immediate cash flow and to retain timber for future earnings, thinning is an option.

8.0 Synthesis of Findings

The following statements are a synthesis of the findings of this study. They are based on sampling six stands and the prediction of growth after thinning.

- Light thinning regimes produced 1 percent to 7 percent more total gross board foot volume than the unthinned regime.
- Heavy thinning regimes produced the least total gross board foot volume.
- Light thinning regimes produced 1 percent to 6 percent more total value than the unthinned regime.
- Heavy thinning regimes produced the least total value.
- The thinning regime with the highest volume did not always have the highest value.
- The regimes that removed the greatest volume during thinning had the highest present net worth.
- Simulated branch removal in the first log did not result in a major increase in value.
- Branches are not the limiting factor in grade designation, ring count and log size are.
- Logging damage to residual trees showed a significant decrease in stand value.
- The growth outcomes of this analysis are based on a computer model. The ability of FVS to accurately portray growth and thinning responses of these stands is not confirmed.

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APPENDIX

Table A.1 Continuous forest inventory plot information.

CFI PLOT	QMD	TPA	BA	SDI	ASPECT	SLOPE	ELEV.
3011	15.0	195	238	372	225	20	5000
3051	11.2	285	196	342	90	30	4000
4191	13.4	195	192	312	180	20	4200
4192	14.3	240	269	427	180	16	4200
4301	9.7	305	155	288	315	20	4900
4322	7.4	125	37	76	360	20	4900
4442	11.2	260	178	312	360	8	4100
5141	10.1	390	92	393	225	5	4200
5341	14.5	80	92	145	315	15	4000
5531	9.7	235	121	225	0	10	4200
CFI PLOT	**AGE**	**TPA %NF**	**TPA %DF**	**PLANT ASSOCATION**			
3011	56	33	67	ABAM/CLUN			
3051	73	30	68	ABAM/CLUN			
4191	?	92	6	TSHE/ACCI			
4192	?	86	14	TSHE/ACCI			
4301	76	15	5	ABAM/CLUN			
4322	60	20	16	ABAM/XETE			
4442	59	33	38	TSHE/XETE			
5141	?	44	12	ABAM/CLUN			
5341	46	19	44	TSHE/XETE			
5531	56	45	23	TSHE/XETE			

Table A.2 BAIMULT adjustments.

BAIMULT adjustments in FVS keyword file:						
Stand:	**Silver fir**	**White fir**	**Mountain hemlock**	**Noble fir**	**Douglas-fir**	**Western hemlock**
B287		1.10		1.90	1.90	
LW7				1.90	1.90	
LW18				1.90	1.90	
LW37	1.05	1.05		1.90	1.90	
LW452		1.95		2.00	1.85	
MW224			1.70	2.00	2.00	1.70

Table A.3 Stand locations and WSIR stand identification numbers.

Stand	**WSIR Identification**	**Road Location**
B287	Beaver - - 287	W300
LW7	Long Willow 3-2-7	W300
LW18	Long Willow 3-2-18	W300
LW37	Long Willow 3-2-37	W300
LW452	Long Willow 3-2-452	spur off W300
MW224	Mount Wilson 1-2-24	S59C

Table A.4 Complete volume and value data sets (a) stand B287, (b) stand LW7, (c) stand LW 18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)

B287: $Value/acre 50 years after treatment					
	Cut $	Residual $	Growth $	$ Val. 2045	TOTAL
1	$ 9,342.2	$ 3,918.2	$ 20,686.6	$ 24,604.8	$ 33,947.0
2	$ 7,920.9	$ 5,339.5	$ 25,955.5	$ 31,295.0	$ 39,215.9
3	$ 6,432.5	$ 6,827.9	$ 29,009.9	$ 35,837.8	$ 42,270.3
4	$ 4,993.9	$ 8,266.5	$ 30,450.0	$ 38,716.5	$ 43,710.4
5	$ 10,251.8	$ 3,008.6	$ 18,134.1	$ 21,142.7	$ 31,394.5
6	$ 9,039.8	$ 4,220.6	$ 22,768.9	$ 26,989.5	$ 36,029.3
7	$ 7,869.9	$ 5,390.5	$ 25,799.1	$ 31,189.6	$ 39,059.5
8	$ 6,658.1	$ 6,602.3	$ 28,127.4	$ 34,729.7	$ 41,387.8
C	$ -	$ 13,260.4	$ 28,156.1	$ 41,416.5	$ 41,416.5
B287: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	Residual	Growth	Vol 2045	TOTAL
1	17,926.1	7,677.1	24,862.5	32,539.6	50,465.7
2	15,367.8	10,235.4	32,086.8	42,322.2	57,690.0
3	12,657.7	12,945.5	37,065.1	50,010.6	62,668.3
4	10,024.5	15,578.7	39,770.4	55,349.1	65,373.6
5	19,793.9	5,809.3	25,176.3	30,985.6	50,779.5
6	17,454.5	8,148.7	31,549.5	39,698.2	57,152.7
7	15,195.2	10,408.0	35,869.3	46,277.3	61,472.5
8	12,855.2	12,748.0	38,819.1	51,567.1	64,422.3
C	0.0	25,603.2	38,748.8	64,352.0	64,352.0
B287: Gross Bd Ft Volume /acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	7,677.1	10,235.4	12,945.5	15,578.7	
2005	12,120.1	16,479.3	20,268.4	23,562.0	
2015	15,811.5	21,913.8	27,494.0	32,087.3	
2025	20,173.0	27,840.0	34,629.4	40,198.0	
2035	25,918.2	34,989.7	42,259.2	47,708.9	
2045	32,539.6	42,322.2	50,010.6	55,349.1	
	R-5	R-6	R-7	R-8	C
1995	5,809.3	8,148.7	10,408.0	12,748.0	25,603.2
2005	9,136.9	12,662.8	15,799.8	19,116.3	35,186.0
2015	13,618.0	18,493.2	22,673.3	26,935.9	44,240.5
2025	18,798.3	24,880.0	29,941.3	35,054.1	52,470.6
2035	24,753.9	31,825.1	37,772.6	43,329.2	58,587.3
2045	30,985.6	39,698.2	46,277.3	51,567.1	64,352.0

Table A.4 (a) Continued

B287: $ Value/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	$3,918.2	$5,339.5	$6,827.9	$8,266.5	
2005	$6,479.4	$8,781.9	$10,784.2	$12,485.8	
2015	$9,505.2	$12,794.1	$15,771.6	$18,231.5	
2025	$13,795.6	$18,256.5	$22,032.4	$25,016.3	
2035	$18,465.1	$24,165.3	$28,283.6	$31,119.3	
2045	$24,604.8	$31,295.0	$35,837.8	$38,716.5	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	$3,008.6	$4,220.6	$5,390.5	$6,602.3	$13,260.4
2005	$4,816.3	$6,662.0	$8,316.6	$10,065.9	$18,596.3
2015	$7,619.3	$10,312.0	$12,550.7	$14,899.0	$24,597.1
2025	$11,236.9	$14,853.3	$17,771.4	$20,709.1	$30,878.5
2035	$16,240.6	$20,644.4	$24,411.3	$27,589.0	$35,651.5
2045	$21,142.7	$26,989.5	$31,189.6	$34,729.7	$41,416.5
B287: Gross Bd Ft 10 yr. growth increment/acre					
	R-1	**R-2**	**R-3**	**R-4**	
2005	4443.0	6243.9	7322.9	7983.3	
2015	3691.4	5434.5	7225.6	8525.3	
2025	4361.5	5926.2	7135.4	8110.7	
2035	5745.2	7149.7	7629.8	7510.9	
2045	6621.4	7332.5	7751.4	7640.2	
mean	**4972.5**	**6417.4**	**7413.0**	**7954.1**	
	R-5	**R-6**	**R-7**	**R-8**	**C**
2005	3327.6	4514.1	5391.8	6368.3	9582.8
2015	4481.1	5830.4	6873.5	7819.6	9054.5
2025	5180.3	6386.8	7268.0	8118.2	8230.1
2035	5955.6	6945.1	7831.3	8275.1	6116.7
2045	6231.7	7873.1	8504.7	8237.9	5764.7
mean	**5035.3**	**6309.9**	**7173.9**	**7763.8**	**7749.8**

Table A. 4 Continued

(b)

LW7: $Value/acre 50 years after treatment					
	Cut $	**Residual $**	**Growth $**	**$ Val. 2045**	**TOTAL**
1	$ 14,489.4	$ 7,418.8	$ 24,257.3	$ 31,676.1	$ 46,165.5
2	$ 11,995.7	$ 9,912.5	$ 31,407.1	$ 41,319.6	$ 53,315.3
3	$ 9,510.9	$ 12,397.3	$ 36,586.8	$ 48,984.1	$ 58,495.0
4	$ 7,326.9	$ 14,581.3	$ 39,085.8	$ 53,667.1	$ 60,994.0
5	$ 16,461.5	$ 5,446.7	$ 23,920.6	$ 29,367.3	$ 45,828.8
6	$ 14,350.8	$ 7,557.4	$ 29,713.6	$ 37,271.0	$ 51,621.8
7	$ 12,173.3	$ 9,734.9	$ 33,397.3	$ 43,132.2	$ 55,305.5
8	$ 9,994.7	$ 11,913.5	$ 36,242.8	$ 48,156.3	$ 58,151.0
C	$ -	$ 21,908.2	$ 36,278.6	$ 58,186.8	$ 58,186.8
LW7: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	**Residual**	**Growth**	**Vol. 2045**	**Total**
1	27,975.4	13,156.7	29,384.3	42,541.0	70,516.4
2	23,298.8	17,833.3	37,180.1	55,013.4	78,312.2
3	18,674.8	22,457.3	42,165.4	64,622.7	83,297.5
4	14,459.9	26,672.2	44,837.4	71,509.6	85,969.5
5	30,906.9	10,225.2	31,050.7	41,275.9	72,182.8
6	26,943.2	14,188.9	38,445.0	52,633.9	79,577.1
7	22,854.5	18,277.6	42,755.8	61,033.4	83,887.9
8	18,764.8	22,367.3	45,505.6	67,872.9	86,637.7
C	0	41,132.1	41,600.1	82,732.2	82,732.2
LW7: Gross Bd Ft Volume/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	13,156.7	17,833.3	22,457.3	26,672.2	
2005	17,366.2	23,034.2	28,863.5	34,637.6	
2015	23,787.6	31,257.9	37,546.5	43,644.0	
2025	29,934.4	39,417.2	47,496.7	53,939.3	
2035	36,372.4	47,476.5	56,385.0	62,972.1	
2045	42,541.0	55,013.4	64,622.7	71,509.6	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	10,225.2	14,188.9	18,277.6	22,367.3	41,132.1
2005	14,403.8	19,754.6	25,115.7	30,167.3	51,504.5
2015	19,444.4	26,358.3	32,937.3	39,022.4	60,622.2
2025	26,164.2	34,726.9	42,092.2	48,736.6	69,195.2
2035	33,708.1	43,560.2	51,875.2	58,415.1	76,364.5
2045	41,275.9	52,633.9	61,033.4	67,872.9	82,732.2

Table A.4 (b) Continued

LW7: $ Value/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	$7,418.8	$9,912.5	$12,397.3	$14,581.3	
2005	$10,998.7	$14,534.4	$17,788.7	$20,902.6	
2015	$15,759.9	$21,131.3	$25,236.8	$28,723.5	
2025	$20,697.1	$27,709.0	$34,169.4	$37,912.7	
2035	$26,119.1	$34,600.6	$41,686.6	$46,001.8	
2045	$31,676.1	$41,319.6	$48,984.1	$53,667.1	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	$5,446.7	$7,557.4	$9,734.9	$11,913.5	$21,908.2
2005	$8,237.8	$11,302.6	$14,378.8	$17,243.4	$29,074.0
2015	$12,112.6	$16,326.4	$20,383.1	$24,100.9	$36,743.9
2025	$17,565.3	$23,233.2	$27,993.4	$32,340.3	$45,202.0
2035	$23,577.5	$30,328.3	$36,218.1	$40,528.4	$51,836.7
2045	$29,367.3	$37,271.0	$43,132.2	$48,156.3	$58,186.8
LW7: Gross Bd Ft 10 yr. growth increment/acre					
	R-1	**R-2**	**R-3**	**R-4**	
2005	4,209.5	5,200.9	6,406.2	7,965.4	
2015	6,421.4	8,223.7	8,683.0	9,006.4	
2025	6,146.8	8,159.3	9,950.2	10,295.3	
2035	6,438.0	8,059.3	8,888.3	9,032.8	
2045	6,168.6	7,536.9	8,237.7	8,537.5	
mean	**5,876.9**	**7,436.0**	**8,433.1**	**8,967.5**	
	R-5	**R-6**	**R-7**	**R-8**	**C**
2005	4,178.6	5,565.7	6,838.1	7,800.0	10,372.4
2015	5,040.6	6,603.7	7,821.6	8,855.1	9,117.7
2025	6,719.8	8,368.6	9,154.9	9,714.2	8,573.0
2035	7,543.9	8,833.3	9,783.0	9,678.5	7,169.3
2045	7,567.8	9,073.7	9,158.2	9,457.8	6,367.7
mean	**6,210.1**	**7,689.0**	**8,551.2**	**9,101.1**	**8,320.0**

Table A.4 Continued

(c)

LW18: $Value/acre 50 years after treatment					
	Cut $	Residual $	Growth $	$ Val. 2045	TOTAL
1	$ 17,641.1	$ 14,067.0	$ 22,460.5	$ 36,527.5	$ 54,168.6
2	$ 12,837.0	$ 18,871.1	$ 28,326.7	$ 47,197.8	$ 60,034.8
3	$ 8,804.1	$ 22,904.0	$ 33,458.1	$ 56,362.1	$ 65,166.2
4	$ 5,576.9	$ 26,131.2	$ 37,410.0	$ 63,541.2	$ 69,118.1
5	$ 21,176.8	$ 10,531.3	$ 21,539.1	$ 32,070.4	$ 53,247.2
6	$ 17,127.8	$ 14,580.3	$ 27,158.5	$ 41,738.8	$ 58,866.6
7	$ 12,961.3	$ 18,746.8	$ 31,763.5	$ 50,510.3	$ 63,471.6
8	$ 8,794.9	$ 22,913.2	$ 34,362.1	$ 57,275.3	$ 66,070.2
C	$ -	$ 31,708.1	$ 36,327.4	$ 68,035.5	$ 68,035.5
LW18: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	**Residual**	**Growth**	**Vol 2045**	**Total**
1	28,246.5	18,966.7	26,344.7	45,311.4	73,557.9
2	21,709.9	25,503.3	34,886.7	60,390.0	82,099.9
3	15,826.2	31,387.0	40,293.2	71,680.2	87,506.4
4	10,374.1	36,839.1	43,957.2	80,796.3	91,170.4
5	31,532.5	15,680.7	26,880.4	42,561.1	74,093.6
6	25,503.0	21,710.2	33,353.3	55,063.5	80,566.5
7	19,299.2	27,914.0	38,160.5	66,074.5	85,373.7
8	13,095.4	34,177.8	41,216.3	75,394.1	88,489.5
C	0	47,213.2	42,228.3	89,441.5	89,441.5
LW18: Gross Bd Ft Volume/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	18,966.7	25,503.3	31,387.0	36,839.1	
2005	24,286.4	32,954.9	40,322.6	46,702.8	
2015	29,303.9	39,253.5	48,275.0	55,907.9	
2025	34,729.5	46,436.0	56,252.6	64,887.8	
2035	39,809.3	53,393.7	64,289.6	72,981.0	
2045	45,311.4	60,390.0	71,680.2	80,796.3	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	15,680.7	21,710.2	27,914.0	34,117.8	47,213.2
2005	20,194.9	27,787.8	35,278.1	42,638.6	57,188.4
2015	25,013.5	33,929.5	42,550.9	50,731.3	66,472.9
2025	30,413.8	40,773.8	50,389.2	59,307.2	74,874.8
2035	36,422.8	47,937.0	58,397.2	67,541.4	82,158.4
2045	42,561.1	55,063.5	66,074.5	75,394.1	89,441.5

Table A.4 (c) Continued

LW18: $ Value/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	$14,067.0	$18,871.1	$22,904.0	$26,131.2	
2005	$17,901.6	$24,206.5	$29,490.0	$33,860.9	
2015	$22,266.1	$29,652.3	$36,209.2	$41,663.0	
2025	$27,142.9	$35,960.3	$43,435.9	$49,169.0	
2035	$31,715.1	$42,008.3	$50,574.3	$56,975.3	
2045	$36,527.5	$47,197.8	$56,362.1	$63,541.2	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	$10,531.3	$14,580.3	$18,746.8	$22,913.2	$31,708.1
2005	$14,007.7	$19,275.2	$24,433.1	$29,523.2	$39,561.0
2015	$18,143.6	$24,551.3	$30,673.2	$36,394.8	$47,394.1
2025	$22,801.2	$30,421.8	$37,278.0	$43,790.8	$54,979.3
2035	$27,399.0	$36,246.0	$44,022.7	$51,324.0	$62,141.7
2045	$32,070.4	$41,738.8	$50,510.3	$57,275.3	$68,035.5
LW18: Gross Bd Ft 10 year growth increment/acre					
	R-1	**R-2**	**R-3**	**R-4**	
2005	5,319.7	7,451.6	8,935.6	9,863.7	
2015	5,017.5	6,298.6	7,952.4	9,205.1	
2025	5,425.6	7,182.5	7,977.6	8,979.9	
2035	5,079.8	6,957.7	8,037.0	8,093.2	
2045	5,502.1	6,996.3	7,390.6	7,815.3	
mean	**5,268.9**	**6,977.3**	**8,058.6**	**8,791.4**	
	R-5	**R-6**	**R-7**	**R-8**	**C**
2005	4,514.2	6,077.6	7,364.1	8,520.8	9,975.2
2015	4,818.6	6,141.7	7,272.8	8,092.7	9,284.5
2025	5,400.3	6,844.3	7,838.3	8,575.9	8,401.9
2035	6,009.0	7,163.2	8,008.0	8,234.2	7,283.6
2045	6,138.3	7,126.5	7,677.3	7,852.7	7,283.1
mean	**5,376.1**	**6,670.7**	**7,632.1**	**8,255.3**	**8,445.7**

Table A.4 Continued

(d)

LW37: $Value/acre 50 years after treatment					
	Cut $	**Residual $**	**Growth $**	**$ Val. 2045**	**TOTAL**
1	$ 17,306.7	$ 10,486.3	$ 21,160.0	$ 31,646.3	$ 48,953.0
2	$ 14,101.3	$ 13,691.7	$ 27,704.4	$ 41,396.1	$ 55,497.4
3	$ 11,076.2	$ 16,716.8	$ 32,930.1	$ 49,646.9	$ 60,723.1
4	$ 8,433.2	$ 19,359.8	$ 35,545.0	$ 54,904.8	$ 63,338.0
5	$ 20,523.8	$ 7,269.2	$ 20,072.8	$ 27,342.0	$ 47,865.8
6	$ 17,546.7	$ 10,246.3	$ 25,434.4	$ 35,680.7	$ 53,227.4
7	$ 14,656.5	$ 13,136.5	$ 29,032.6	$ 42,169.1	$ 56,825.6
8	$ 11,765.1	$ 16,027.9	$ 31,138.7	$ 47,166.6	$ 58,931.7
C	$ -	$ 27,793.0	$ 31,641.0	$ 59,434.0	$ 59,434.0
LW37: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	**Residual**	**Growth**	**Vol 2045**	**Total**
1	31,409.1	15,261.9	26,095.4	41,357.3	72,766.4
2	26,192.3	20,478.7	32,957.4	53,436.1	79,628.4
3	20,924.0	25,747.0	38,387.3	64,134.3	85,058.3
4	15,932.6	30,738.4	39,989.0	70,727.4	86,660.0
5	34,464.3	12,206.7	23,873.7	36,080.4	70,544.7
6	29,465.0	17,206.0	30,367.7	47,573.7	77,038.7
7	24,611.4	22,059.6	34,539.1	56,598.7	81,210.1
8	19,756.4	26,914.6	37,024.4	63,939.0	83,695.4
C	0	46,671.0	36,017.6	82,688.6	82,688.6
LW37: Gross Bd Ft Volume/acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	15,261.9	20,478.7	25,747.0	30,738.4	
2005	20,019.9	26,249.7	32,093.0	38,015.6	
2015	25,186.1	33,194.2	40,290.4	46,098.0	
2025	30,083.9	39,711.1	48,664.1	55,173.2	
2035	36,101.6	47,317.4	56,718.9	63,316.4	
2045	41,357.3	53,436.1	64,134.3	70,727.4	
	R-5	R-6	R-7	R-8	C
1995	12,206.7	17,206.0	22,059.6	26,914.6	46,671.0
2005	15,717.9	22,027.6	27,937.9	33,818.3	56,005.3
2015	19,877.8	27,537.7	34,389.2	41,102.6	64,040.2
2025	24,659.0	33,485.8	41,651.6	48,901.8	70,788.2
2035	30,484.3	40,815.4	49,231.3	56,770.5	77,083.2
2045	36,080.4	47,573.7	56,598.7	63,939.0	82,688.6

Table A.4 (d) Continued

LW37: $ Value/acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	$10,486.3	$13,691.7	$16,716.8	$19,359.8	
2005	$14,230.0	$18,577.2	$22,056.7	$25,307.3	
2015	$18,709.0	$24,549.0	$29,021.7	$32,420.1	
2025	$23,343.5	$30,473.9	$36,796.4	$41,104.0	
2035	$28,927.0	$37,742.8	$44,442.1	$48,690.2	
2045	$31,646.3	$41,396.1	$49,646.9	$54,904.8	
	R-5	R-6	R-7	R-8	C
1995	$7,269.2	$10,246.3	$13,136.5	$16,027.9	$27,793.0
2005	$9,802.8	$13,739.9	$17,341.5	$20,997.0	$34,485.6
2015	$13,310.2	$18,402.9	$22,993.9	$27,300.2	$41,634.9
2025	$17,295.4	$23,340.6	$28,988.8	$33,905.9	$48,574.5
2035	$22,134.5	$29,446.1	$35,764.8	$40,856.7	$54,924.1
2045	$27,342.0	$35,680.7	$42,169.1	$47,166.6	$59,434.0
LW37: Gross Bd Ft 10 year growth increment/acre					
	R-1	R-2	R-3	R-4	
2005	4,758.0	5,771.0	6,346.0	7,277.2	
2015	5,166.2	6,944.5	8,197.4	8,082.4	
2025	4,897.8	6,516.9	8,373.7	9,075.2	
2035	6,017.7	7,606.3	8,054.8	8,143.2	
2045	5,255.7	6,118.7	7,415.4	7,411.0	
mean	**5,219.1**	**6,591.5**	**7,677.5**	**7,997.8**	
	R-5	R-6	R-7	R-8	C
2005	3,511.2	4,821.6	5,878.3	6,903.7	9,334.3
2015	4,159.9	5,510.1	6,451.3	7,284.3	8,034.9
2025	4,781.2	5,948.1	7,262.4	7,799.2	6,748.0
2035	5,825.3	7,329.6	7,579.7	7,868.7	6,295.0
2045	5,596.1	6,758.3	7,367.4	7,168.5	5,605.4
mean	**4,774.7**	**6,073.5**	**6,907.8**	**7,404.9**	**7,203.5**

Table A.4 Continued

(e)

LW452: $Value/acre 50 years after treatment					
	Cut $	Residual $	Growth $	$ Val. 2045	TOTAL
1	$ 14,626.3	$ 8,342.3	$ 21,846.5	$ 30,188.8	$ 44,815.1
2	$ 12,115.8	$ 10,852.8	$ 28,068.8	$ 38,921.6	$ 51,037.4
3	$ 9,462.8	$ 13,505.8	$ 31,532.3	$ 45,038.1	$ 54,500.9
4	$ 7,168.6	$ 15,800.0	$ 34,049.4	$ 49,849.4	$ 57,018.0
5	$ 17,083.3	$ 5,885.3	$ 18,408.7	$ 24,294.0	$ 41,377.3
6	$ 14,715.1	$ 8,253.5	$ 23,397.2	$ 31,650.7	$ 46,365.8
7	$ 12,417.4	$ 10,551.2	$ 26,865.7	$ 37,416.9	$ 49,834.3
8	$ 10,048.4	$ 12,920.2	$ 29,701.9	$ 42,622.1	$ 52,670.5
C	$ -	$ 22,968.6	$ 30,649.9	$ 53,618.5	$ 53,618.5
LW452: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	Residual	Growth	Vol 2045	Total
1	27,260.0	12,687.3	26,771.8	39,459.1	66,719.1
2	22,887.3	17,060.0	33,209.3	50,269.3	73,156.6
3	18,063.2	21,884.1	37,650.4	59,534.5	77,597.7
4	13,619.3	26,328.0	41,757.8	68,085.8	81,705.1
5	29,711.6	10,235.7	25,419.5	35,655.2	65,366.8
6	25,591.4	14,355.9	32,004.0	46,359.9	71,951.3
7	21,596.9	18,350.4	36,277.3	54,627.7	76,224.6
8	17,476.0	22,471.3	39,090.1	61,561.4	79,037.4
C	0	39,947.3	37,922.3	77,869.6	77,869.6
LW452: Gross Bd Ft Volume/acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	12,687.3	17,060.0	21,884.1	26,328.0	
2005	17,059.4	22,413.5	27,935.0	33,698.0	
2015	22,488.6	29,740.1	35,988.9	41,822.6	
2025	28,249.7	36,778.8	44,514.0	51,250.1	
2035	33,902.1	44,126.1	53,539.7	60,670.7	
2045	39,459.1	50,269.3	59,534.5	68,085.8	
	R-5	R-6	R-7	R-8	C
1995	10,235.7	14,355.9	18,350.4	22,471.3	39,947.3
2005	13,749.8	19,124.3	24,192.7	29,222.9	48,911.0
2015	18,173.9	25,011.4	30,895.4	36,844.5	57,252.8
2025	23,642.1	31,872.6	39,073.9	45,494.2	65,367.7
2035	29,729.0	39,447.8	46,925.1	53,860.1	72,672.2
2045	35,655.2	46,359.9	54,627.7	61,561.4	77,869.6

Table A.4 (e) Continued

LW452: $ Value/acre after treatment at 10 yr intervals					
	R-1	**R-2**	**R-3**	**R-4**	
1995	$8,342.3	$10,852.8	$13,505.8	$15,800.0	
2005	$12,906.9	$16,671.4	$19,890.3	$22,930.0	
2015	$16,878.0	$22,470.2	$26,384.8	$29,713.4	
2025	$21,483.8	$27,460.2	$32,796.4	$36,668.6	
2035	$24,755.0	$32,865.9	$39,824.5	$44,335.0	
2045	$30,188.8	$38,921.6	$45,038.1	$49,849.4	
	R-5	**R-6**	**R-7**	**R-8**	**C**
1995	$5,885.3	$8,253.5	$10,551.2	$12,920.2	$22,968.6
2005	$8,724.6	$12,139.0	$15,349.6	$18,528.8	$30,801.8
2015	$12,118.5	$16,681.2	$20,523.1	$24,413.1	$37,561.4
2025	$16,015.7	$21,507.2	$26,315.0	$30,554.9	$43,684.3
2035	$20,814.8	$27,531.6	$32,375.7	$36,732.1	$49,700.2
2045	$24,294.0	$31,650.7	$37,416.9	$42,622.1	$53,618.5
LW452: Gross Bd Ft 10 yr growth increment/acre					
	R-1	**R-2**	**R-3**	**R-4**	
2005	4,372.1	5,353.5	6,050.9	7,370.0	
2015	5,429.2	7,326.6	8,053.9	8,124.6	
2025	5,761.1	7,038.7	8,525.1	9,427.5	
2035	5,652.4	7,347.3	9,025.7	9,420.6	
2045	5,557.0	6,143.2	5,994.8	7,415.1	
mean	**5,354.4**	**6,641.9**	**7,530.1**	**8,351.6**	
	R-5	**R-6**	**R-7**	**R-8**	**C**
2005	3,514.1	4,768.4	5,842.3	6,751.6	8,963.7
2015	4,424.1	5,887.1	6,702.7	7,621.6	8,341.8
2025	5,468.2	6,861.2	8,178.5	8,649.7	8,114.9
2035	6,086.9	7,575.2	7,851.2	8,365.9	7,304.5
2045	5,926.2	6,912.1	7,702.6	7,701.3	5,197.4
mean	**5,083.9**	**6,400.8**	**7,255.5**	**7,818.0**	**7,584.5**

Table A.4 Continued

(f)

MW224: $Value/acre 50 years after treatment					
	Cut $	Residual $	Growth $	$ Val. 2045	TOTAL
1	$ 12,631.0	$ 5,375.8	$ 15,465.0	$ 20,840.8	$ 33,471.8
2	$ 10,270.5	$ 7,736.3	$ 24,360.3	$ 32,096.6	$ 42,367.1
3	$ 8,164.3	$ 9,842.5	$ 28,628.3	$ 38,470.8	$ 46,635.1
4	$ 6,321.8	$ 11,685.0	$ 31,348.9	$ 43,033.9	$ 49,355.7
5	$ 13,810.7	$ 4,196.1	$ 23,463.2	$ 27,659.3	$ 41,470.0
6	$ 12,131.6	$ 5,875.2	$ 28,106.9	$ 33,982.1	$ 46,113.7
7	$ 10,452.6	$ 7,554.2	$ 31,613.3	$ 39,167.5	$ 49,620.1
8	$ 8,773.9	$ 9,232.9	$ 32,667.9	$ 41,900.8	$ 50,674.7
C	$ -	$ 18,006.8	$ 30,128.7	$ 48,135.5	$ 48,135.5
MW224: Gross Bd Ft Volume/acre 50 years after treatment					
	Cut	Residual	Growth	Vol 2045	Total
1	24,488.2	14,827.2	27,199.5	42,026.7	66,514.9
2	19,852.5	19,462.9	36,354.6	55,817.5	75,670.0
3	15,744.3	23,571.1	42,261.0	65,832.1	81,576.4
4	12,280.2	27,035.2	44,966.0	72,001.2	84,281.4
5	30,151.5	9,163.9	33,892.5	43,056.4	73,207.9
6	26,487.8	12,827.6	40,980.7	53,808.3	80,296.1
7	22,820.1	16,459.3	45,366.7	61,826.0	84,646.1
8	19,155.5	20,159.9	47,191.0	67,350.9	86,506.4
C	0	39,315.4	41,028.2	80,343.6	80,343.6
MW224: Gross Bd Ft Volume/acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	14,827.2	19,462.9	23,571.1	27,035.2	
2005	18,997.0	25,140.9	30,856.7	35,419.6	
2015	24,439.0	31,644.1	38,358.3	44,005.7	
2025	30,348.5	40,630.8	47,805.3	53,798.1	
2035	36,262.3	48,284.1	56,960.1	62,986.8	
2045	42,026.7	55,817.5	65,832.1	72,001.2	
	R-5	R-6	R-7	R-8	C
1995	9,163.9	12,827.6	16,495.3	20,159.9	39,315.4
2005	13,250.9	18,348.7	23,203.2	27,823.4	48,526.4
2015	18,764.3	25,612.1	31,663.7	36,967.0	58,112.7
2025	26,015.7	34,389.3	41,668.2	47,806.9	66,964.7
2035	34,150.2	44,061.0	52,057.9	58,182.8	74,423.5
2045	43,056.4	53,808.3	61,826.0	67,350.9	80,343.6

Table A.4 (f) Continued

MW224: $ Value/acre after treatment at 10 yr intervals					
	R-1	R-2	R-3	R-4	
1995	$5,375.8	$7,736.3	$9,842.5	$11,685.0	
2005	$8,182.6	$11,667.5	$14,655.9	$17,082.2	
2015	$11,708.7	$15,991.9	$19,837.5	$22,973.8	
2025	$15,186.5	$21,805.4	$26,131.7	$29,763.3	
2035	$18,067.8	$26,805.2	$33,078.1	$36,968.8	
2045	$20,840.8	$32,096.6	$38,470.8	$43,033.9	
	R-5	R-6	R-7	R-8	C
1995	$4,196.1	$5,875.2	$7,554.2	$9,232.9	$18,006.8
2005	$6,577.9	$9,097.8	$11,503.9	$13,761.3	$23,843.6
2015	$10,057.9	$13,660.7	$16,842.0	$19,620.3	$30,267.0
2025	$15,089.0	$19,643.1	$23,591.6	$26,937.7	$36,689.1
2035	$20,917.3	$26,918.5	$31,631.4	$34,959.4	$43,178.1
2045	$27,659.3	$33,982.1	$39,167.5	$41,900.8	$48,135.5
MW224: Gross Bd Ft 10 year growth increment/acre					
	R-1	R-2	R-3	R-4	
2005	4,169.8	5,678.0	7,285.6	8,384.4	
2015	5,442.0	6,503.2	7,501.6	8,586.1	
2025	5,909.5	8,986.7	9,447.0	9,792.4	
2035	5,913.8	7,653.3	9,154.8	9,188.7	
2045	5,764.4	7,533.4	8,872.0	9,014.4	
mean	**5,439.9**	**7,270.9**	**8,452.2**	**8,993.2**	
	R-5	R-6	R-7	R-8	C
2005	4,087.0	5,521.1	6,707.9	7,663.5	9,211.0
2015	5,513.4	7,263.4	8,460.5	9,143.6	9,586.3
2025	7,251.4	8,777.2	10,004.5	10,839.9	8,852.0
2035	8,134.5	9,671.7	10,389.7	10,375.9	7,458.8
2045	8,906.2	9,747.3	9,768.1	9,168.1	5,920.1
mean	**6,778.5**	**8,196.1**	**9,066.1**	**9,438.2**	**8,205.6**

Table A.5 Forty largest trees per acre.

LW7 40 Largest trees per acre				
Regime	**Year**	**Mean DBH**	**Mean HT**	**Mean LCR**
Control	**1995**	21.51	96.65	53.05%
	2005	22.98	107.85	53.08%
	2015	24.69	117.48	53.48%
	2025	26.56	126.08	54.05%
	2035	28.46	133.94	54.13%
	2045	30.34	140.10	54.48%
R-1	**1995**	21.51	96.65	53.05%
	2005	23.04	107.92	49.65%
	2015	24.72	117.32	50.70%
	2025	26.55	125.78	51.20%
	2035	28.39	133.50	51.80%
	2045	30.19	139.64	52.25%
R-2	**1995**	21.51	96.65	53.05%
	2005	23.02	107.91	50.73%
	2015	24.71	117.42	53.18%
	2025	26.59	125.98	54.80%
	2035	28.52	133.83	55.28%
	2045	30.40	140.04	55.88%
R-3	**1995**	21.51	96.65	53.05%
	2005	23.01	107.88	51.93%
	2015	24.72	117.43	54.50%
	2025	26.62	126.63	56.40%
	2035	28.57	133.96	56.78%
	2045	30.48	140.18	57.03%
R-4	**1995**	21.51	96.65	53.05%
	2005	23.01	107.88	52.75%
	2015	24.73	117.48	55.35%
	2025	26.65	126.15	56.70%
	2035	28.60	134.02	57.08%
	2045	30.52	140.25	56.45%

Table A.5 Continued

Regime	Year	Mean DBH	Mean HT	
R-5	1995	21.51	96.65	53.05%
	2005	23.16	107.96	56.10%
	2015	25.14	118.11	59.28%
	2025	27.35	127.12	61.20%
	2035	29.60	134.55	62.65%
	2045	31.80	140.86	63.60%
R-6	1995	21.51	96.65	53.05%
	2005	23.13	107.96	56.10%
	2015	25.09	118.09	59.23%
	2025	27.26	127.08	61.13%
	2035	29.47	134.50	62.55%
	2045	31.63	140.62	63.45%
R-7	1995	21.51	96.65	53.05%
	2005	23.11	107.91	56.10%
	2015	25.03	118.09	58.88%
	2025	27.17	127.05	61.03%
	2035	29.34	134.47	62.45%
	2045	31.47	140.59	62.60%
R-8	1995	21.51	96.65	53.05%
	2005	23.08	107.90	56.10%
	2015	24.97	118.09	58.83%
	2025	27.08	127.04	60.88%
	2035	29.22	134.45	61.10%
	2045	31.30	140.73	61.15%

Table A.6 Present net worth analysis (a) stand B287, (b) stand LW7, (c) stand LW 18, (d) stand LW37, (e) stand LW452, and (f) stand MW224.

(a)

B287: PNW Analysis (all figures are on a per acre basis)				
Regime	**1995 Vol Cut**	**2045 Vol Cut**	**Total Vol Cut**	**1995 Net Revenue**
1	17926.1	32539.6	50465.7	$ 7,424.1
2	15367.8	42322.2	57690.0	$ 6,276.5
3	12657.7	50010.6	62668.3	$ 5,078.1
4	10024.5	55349.1	65373.6	$ 3,921.3
5	19793.9	30985.6	50779.5	$ 8,133.9
6	17454.5	39698.2	57152.7	$ 7,172.2
7	15195.2	46277.3	61472.5	$ 6,244.0
8	12855.2	51567.1	64422.3	$ 5,282.6
C	0.0	64352.0	64352.0	$ -
CC	25603.2	0.0	25603.2	$ 10,520.9
No price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 10,396.4	$ 8,141.2	$ 7,604.0
2		$ 10,042.9	$ 7,185.2	$ 6,504.6
3		$ 9,368.0	$ 6,113.1	$ 5,337.8
4		$ 8,535.8	$ 5,034.6	$ 4,200.6
5		$ 10,642.4	$ 8,739.0	$ 8,285.7
6		$ 10,372.2	$ 7,944.2	$ 7,365.9
7		$ 9,936.0	$ 7,134.7	$ 6,467.5
8		$ 9,393.1	$ 6,274.3	$ 5,531.4
C		$ 4,858.9	$ 1,172.2	$ 294.2
CC		$ 10,520.9	$ 10,520.9	$ 10,520.9
1% Price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
R-1		$ 12,628.2	$ 8,679.6	$ 7,739.2
R-2		$ 12,881.6	$ 7,870.1	$ 6,676.4
R-3		$ 12,618.8	$ 6,897.3	$ 5,534.6
R-4		$ 12,047.7	$ 5,881.8	$ 4,413.2
R-5		$ 12,560.2	$ 9,201.7	$ 8,401.8
R-6		$ 12,820.4	$ 8,534.8	$ 7,514.1
R-7		$ 12,765.2	$ 7,817.3	$ 6,638.8
R-8		$ 12,543.3	$ 7,034.3	$ 5,722.1
C		$ 8,615.7	$ 2,078.6	$ 521.6
CC		$ 10,520.9	$ 10,520.9	$ 10,520.9

Table A.6 Continued

(b)

LW7: PNW Analysis (all values are on a per acre basis)				
Regime	1995 Vol Cut	2045 Vol Cut	Total Vol Cut	1995 Net Revenue
1	27975.4	42541.0	70516.4	$ 11,496.0
2	23298.8	55013.4	78312.2	$ 9,502.7
3	18674.8	64622.7	83297.5	$ 7,512.7
4	14459.9	71509.6	85969.5	$ 5,779.7
5	30906.9	41275.9	72182.8	$ 13,154.5
6	26943.2	52633.9	79577.1	$ 11,467.9
7	22854.5	61033.4	83887.9	$ 9,727.9
8	18764.8	67872.9	86637.7	$ 7,986.9
C	0.0	82732.2	82732.2	$ -
CC	41132.1	0.0	41132.1	$ 17,507.1
No price increase		4% Discount Rate	7% Discount Rate	10% Discount Rate
Regime		Total Net Revenue	Total Net Revenue	Total Net Revenue
1		$ 15,312.8	$ 12,416.8	$ 11,727.1
2		$ 14,488.6	$ 10,705.6	$ 9,804.6
3		$ 13,432.4	$ 8,940.9	$ 7,871.1
4		$ 12,254.7	$ 7,341.8	$ 6,171.7
5		$ 16,665.4	$ 14,001.5	$ 13,367.0
6		$ 15,919.9	$ 12,542.0	$ 11,737.4
7		$ 14,878.2	$ 10,970.4	$ 10,039.7
8		$ 13,741.2	$ 9,375.1	$ 8,335.2
C		$ 6,942.0	$ 1,674.8	$ 420.3
CC		$ 17,507.1	$ 17,507.1	$ 17,507.1
1% Price increase				
LW7		4% Discount Rate	7% Discount Rate	10% Discount Rate
Regime		Total Net Revenue	Total Net Revenue	Total Net Revenue
1		$ 18,186.0	$ 13,110.0	$ 11,901.0
2		$ 18,236.6	$ 11,609.8	$ 10,031.5
3		$ 17,875.6	$ 10,012.8	$ 8,140.1
4		$ 17,122.7	$ 8,516.3	$ 6,466.4
5		$ 19,329.2	$ 14,644.2	$ 13,528.3
6		$ 19,300.7	$ 13,357.6	$ 11,942.1
7		$ 18,790.6	$ 11,914.3	$ 10,276.5
8		$ 18,109.3	$ 10,429.0	$ 8,599.7
C		$ 12,220.0	$ 2,948.1	$ 739.8
CC		$ 17,507.1	$ 17,507.1	$ 17,507.1

Table A.6 Continued

(c)

LW18: PNW Analysis (all figures are on a per acre basis)					
Regime	**1995 Vol Cut**	**2045 Vol Cut**	**Total Vol Cut**	**1995 Net Revenue**	
1	28246.5	45311.4	73557.9	$	14,618.7
2	21709.9	60390.0	82099.9	$	10,514.0
3	15826.2	71680.2	87506.4	$	7,110.7
4	10374.1	80796.3	91170.4	$	4,466.9
5	31532.5	42561.1	74093.6	$	17,802.8
6	25503.0	55063.5	80566.5	$	14,399.0
7	19299.2	66074.5	85373.7	$	10,896.3
8	13095.4	75394.1	88489.5	$	7,393.7
C	0.0	89441.5	89441.5	$	-
CC	47213.2	0.0	47213.2	$	26,656.3
No price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**	
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**	
1		$ 19,076.4	$ 15,694.2	$	14,888.6
2		$ 16,246.1	$ 11,896.9	$	10,861.1
3		$ 13,962.3	$ 8,763.7	$	7,525.5
4		$ 12,191.4	$ 6,330.5	$	4,934.5
5		$ 21,674.7	$ 18,736.9	$	18,037.2
6		$ 19,443.1	$ 15,615.9	$	14,704.3
7		$ 17,008.9	$ 12,371.0	$	11,266.3
8		$ 14,317.9	$ 9,064.2	$	7,812.9
C		$ 8,226.8	$ 1,984.8	$	498.0
CC		$ 26,656.3	$ 26,656.3	$	26,656.3
1% Price Increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**	
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**	
1		$ 22,389.7	$ 16,493.5	$	15,089.2
2		$ 20,527.3	$ 12,929.8	$	11,120.2
3		$ 19,074.8	$ 9,997.1	$	7,835.0
4		$ 17,955.1	$ 7,721.0	$	5,283.4
5		$ 24,583.8	$ 19,438.8	$	18,213.3
6		$ 23,229.1	$ 16,529.3	$	14,933.5
7		$ 21,590.6	$ 13,476.3	$	11,543.7
8		$ 19,513.2	$ 10,317.6	$	8,127.4
C		$ 14,398.2	$ 3,473.6	$	871.6
CC		$ 26,656.3	$ 26,656.3	$	26,656.3

Table A.6 Continued

(d)

LW37: PNW Analysis (all figures are on a per acre basis)				
Regime	**1995 Vol Cut**	**2045 Vol Cut**	**Total Vol Cut**	**1995 Net Revenue**
1	31409.1	41357.3	72766.4	$ 13,945.9
2	26192.3	53436.1	79628.4	$ 11,298.7
3	20924.0	64134.3	85058.3	$ 8,837.3
4	15932.6	70727.4	86660.0	$ 6,728.4
5	34464.3	36080.4	70544.7	$ 16,836.1
6	29465.0	47573.7	77038.7	$ 14,393.9
7	24611.4	56598.7	81210.1	$ 12,023.1
8	19756.4	63939.0	83695.4	$ 9,651.2
C	0.0	82688.6	82688.6	$ -
CC	46671.0	0.0	46671.0	$ 22,799.2
No price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 17,776.3	$ 14,870.0	$ 14,177.8
2		$ 16,319.1	$ 12,509.9	$ 11,602.7
3		$ 14,857.7	$ 10,289.8	$ 9,201.8
4		$ 13,389.3	$ 8,335.4	$ 7,131.7
5		$ 20,140.2	$ 17,633.3	$ 17,036.1
6		$ 18,698.4	$ 15,432.4	$ 14,654.5
7		$ 17,104.6	$ 13,249.0	$ 12,330.7
8		$ 15,325.4	$ 11,020.1	$ 9,994.7
C		$ 7,118.1	$ 1,717.3	$ 430.9
CC		$ 22,799.2	$ 22,799.2	$ 22,799.2
1% Price Increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 20,646.8	$ 15,562.6	$ 14,351.6
2		$ 20,074.1	$ 13,415.8	$ 11,830.0
3		$ 19,361.0	$ 11,376.2	$ 9,474.4
4		$ 18,369.6	$ 9,536.9	$ 7,433.2
5		$ 22,620.4	$ 18,231.6	$ 17,186.3
6		$ 21,934.9	$ 16,213.2	$ 14,850.5
7		$ 20,929.7	$ 14,171.9	$ 12,562.3
8		$ 19,603.8	$ 12,052.3	$ 10,253.7
C		$ 12,509.3	$ 3,017.9	$ 757.3
CC		$ 22,799.2	$ 22,799.2	$ 22,799.2

Table A.6 Continued

(e)

LW452: PNW Analysis (all values are on a per acre basis)				
Regime	**1995 Vol Cut**	**2045 Vol Cut**	**Total Vol Cut**	**1995 Net Revenue**
1	27260.0	39459.1	66719.1	$ 11,709.5
2	22887.3	50269.3	73156.6	$ 9,666.9
3	18063.2	59534.5	77597.7	$ 7,530.0
4	13619.3	68085.8	81705.1	$ 5,711.3
5	29711.6	35655.2	65366.8	$ 13,904.2
6	25591.4	46359.9	71951.3	$ 11,976.8
7	21596.9	54627.7	76224.6	$ 10,106.5
8	17476.0	61561.4	79037.4	$ 8,178.5
C	0.0	77869.6	77869.6	$ -
CC	39947.3	0.0	39947.3	$ 18,694.2
No price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 15,363.3	$ 12,591.0	$ 11,930.7
2		$ 14,386.8	$ 10,805.6	$ 9,952.6
3		$ 12,971.1	$ 8,842.7	$ 7,859.4
4		$ 11,700.7	$ 7,156.3	$ 6,073.9
5		$ 16,785.8	$ 14,599.4	$ 14,078.6
6		$ 15,732.5	$ 12,882.9	$ 12,204.2
7		$ 14,549.1	$ 11,178.3	$ 10,375.5
8		$ 13,249.1	$ 9,401.8	$ 8,485.4
C		$ 6,372.4	$ 1,537.4	$ 385.8
CC		$ 18,694.2	$ 18,694.2	$ 18,694.2
1% Price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 18,101.7	$ 13,251.6	$ 12,096.5
2		$ 17,917.2	$ 11,657.3	$ 10,166.3
3		$ 17,056.4	$ 9,828.3	$ 8,106.8
4		$ 16,222.4	$ 8,247.2	$ 6,347.7
5		$ 18,989.5	$ 15,131.0	$ 14,212.0
6		$ 18,603.4	$ 13,575.5	$ 12,378.0
7		$ 17,943.1	$ 11,997.1	$ 10,580.9
8		$ 17,115.2	$ 10,334.5	$ 8,719.5
C		$ 11,236.0	$ 2,710.8	$ 680.2
CC		$ 18,694.2	$ 18,694.2	$ 18,694.2

Table A.6 Continued

(f)

MW224: PNW Analysis (all values are on a per acre basis)				
Regime	**1995 Vol Cut**	**2045 Vol Cut**	**Total Vol Cut**	**1995 Net Revenue**
1	24488.2	42026.7	66514.9	$ 10,010.8
2	19852.5	55817.5	75670.0	$ 8,146.3
3	15744.3	65832.1	81576.4	$ 6,479.7
4	12280.2	72001.2	84281.4	$ 5,007.8
5	30151.5	43056.4	73207.9	$ 10,584.5
6	26487.8	53808.3	80296.1	$ 9,297.4
7	22820.1	61826.0	84646.1	$ 8,010.8
8	19155.5	67350.9	86506.4	$ 6,724.3
C	0.0	80343.6	80343.6	$ -
CC	39315.4	0.0	39315.4	$ 13,800.1
No price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 12,310.6	$ 10,565.6	$ 10,150.0
2		$ 11,822.3	$ 9,033.1	$ 8,368.8
3		$ 10,901.8	$ 7,546.5	$ 6,747.4
4		$ 9,979.2	$ 6,207.2	$ 5,308.8
5		$ 13,828.2	$ 11,367.1	$ 10,780.9
6		$ 13,269.0	$ 10,255.6	$ 9,537.8
7		$ 12,591.3	$ 9,115.9	$ 8,288.1
8		$ 11,606.2	$ 7,902.1	$ 7,019.8
C		$ 5,563.6	$ 1,342.3	$ 336.8
CC		$ 13,800.1	$ 13,800.1	$ 13,800.1
1% Price increase		**4% Discount Rate**	**7% Discount Rate**	**10% Discount Rate**
Regime		**Total Net Revenue**	**Total Net Revenue**	**Total Net Revenue**
1		$ 14,201.0	$ 11,021.7	$ 10,264.4
2		$ 14,733.7	$ 9,735.5	$ 8,545.1
3		$ 14,391.4	$ 8,388.4	$ 6,958.6
4		$ 13,882.7	$ 7,148.9	$ 5,545.1
5		$ 16,337.1	$ 11,972.4	$ 10,932.7
6		$ 16,351.4	$ 10,999.2	$ 9,724.4
7		$ 16,144.1	$ 9,973.1	$ 8,503.2
8		$ 15,406.9	$ 8,819.0	$ 7,249.9
C		$ 9,929.9	$ 2,395.6	$ 601.1
CC		$ 13,800.1	$ 13,800.1	$ 13,800.1

Table A.6 (Continued)

Total Net Revenue 50 yrs after Treament Percent of Clearcut Regime:							
B287	**Total Net Revenue**				**Total Net Revenue**		
	No price increase				**1% price increase**		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	98.8%	77.4%	72.3%		120.0%	82.5%	73.6%
R-2	95.5%	68.3%	61.8%		122.4%	74.8%	63.5%
R-3	89.0%	58.1%	50.7%		119.9%	65.6%	52.6%
R-4	81.1%	47.9%	39.9%		114.5%	55.9%	41.9%
R-5	101.2%	83.1%	78.8%		119.4%	87.5%	79.9%
R-6	98.6%	75.5%	70.0%		121.9%	81.1%	71.4%
R-7	94.4%	67.8%	61.5%		121.3%	74.3%	63.1%
R-8	89.3%	59.6%	52.6%		119.2%	66.9%	54.4%
Control	46.2%	11.1%	2.8%		81.9%	19.8%	5.0%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%
LW7	**No price increase**				**1% price increase**		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	87.5%	70.9%	67.0%		103.9%	74.9%	68.0%
R-2	82.8%	61.2%	56.0%		104.2%	66.3%	57.3%
R-3	76.7%	51.1%	45.0%		102.1%	57.2%	46.5%
R-4	70.0%	41.9%	35.3%		97.8%	48.6%	36.9%
R-5	95.2%	80.0%	76.4%		110.4%	83.6%	77.3%
R-6	90.9%	71.6%	67.0%		110.2%	76.3%	68.2%
R-7	85.0%	62.7%	57.3%		107.3%	68.1%	58.7%
R-8	78.5%	53.6%	47.6%		103.4%	59.6%	49.1%
Control	39.7%	9.6%	2.4%		69.8%	16.8%	4.2%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%
LW18	**No price increase**				**1% price increase**		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	71.6%	58.9%	55.9%		84.0%	61.9%	56.6%
R-2	60.9%	44.6%	40.7%		77.0%	48.5%	41.7%
R-3	52.4%	32.9%	28.2%		71.6%	37.5%	29.4%
R-4	45.7%	23.7%	18.5%		67.4%	29.0%	19.8%
R-5	81.3%	70.3%	67.7%		92.2%	72.9%	68.3%
R-6	72.9%	58.6%	55.2%		87.1%	62.0%	56.0%
R-7	63.8%	46.4%	42.3%		81.0%	50.6%	43.3%
R-8	53.7%	34.0%	29.3%		73.2%	38.7%	30.5%
Control	30.9%	7.4%	1.9%		54.0%	13.0%	3.3%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Table A.6 (Continued)

LW37	No price increase				1% price increase		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	78.0%	65.2%	62.2%		90.6%	68.3%	62.9%
R-2	71.6%	54.9%	50.9%		88.0%	58.8%	51.9%
R-3	65.2%	45.1%	40.4%		84.9%	49.9%	41.6%
R-4	58.7%	36.6%	31.3%		80.6%	41.8%	32.6%
R-5	88.3%	77.3%	74.7%		99.2%	80.0%	75.4%
R-6	82.0%	67.7%	64.3%		96.2%	71.1%	65.1%
R-7	75.0%	58.1%	54.1%		91.8%	62.2%	55.1%
R-8	67.2%	48.3%	43.8%		86.0%	52.9%	45.0%
Control	31.2%	7.5%	1.9%		54.9%	13.2%	3.3%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%
LW452	**No price increase**				**1% price increase**		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	82.2%	67.4%	63.8%		96.8%	70.9%	64.7%
R-2	77.0%	57.8%	53.2%		95.8%	62.4%	54.4%
R-3	69.4%	47.3%	42.0%		91.2%	52.6%	43.4%
R-4	62.6%	38.3%	32.5%		86.8%	44.1%	34.0%
R-5	89.8%	78.1%	75.3%		101.6%	80.9%	76.0%
R-6	84.2%	68.9%	65.3%		99.5%	72.6%	66.2%
R-7	77.8%	59.8%	55.5%		96.0%	64.2%	56.6%
R-8	70.9%	50.3%	45.4%		91.6%	55.3%	46.6%
Control	34.1%	8.2%	2.1%		60.1%	14.5%	3.6%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%
MW224	**No price increase**				**1% price increase**		
Regime	**4% DR**	**7% DR**	**10% DR**		**4% DR**	**7% DR**	**10% DR**
R-1	89.2%	76.6%	73.6%		102.9%	79.9%	74.4%
R-2	85.7%	65.5%	60.6%		106.8%	70.5%	61.9%
R-3	79.0%	54.7%	48.9%		104.3%	60.8%	50.4%
R-4	72.3%	45.0%	38.5%		100.6%	51.8%	40.2%
R-5	100.2%	82.4%	78.1%		118.4%	86.8%	79.2%
R-6	96.2%	74.3%	69.1%		118.5%	79.7%	70.5%
R-7	91.2%	66.1%	60.1%		117.0%	72.3%	61.6%
R-8	84.1%	57.3%	50.9%		111.6%	63.9%	52.5%
Control	40.3%	9.7%	2.4%		72.0%	17.4%	4.4%
Clearcut	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Table A.7 Individual tree damage loss analysis.

(all values are on a per acre basis)					
	2045	Total 2045	minus DF	2045	2045
Regime	mean $/BF	Bd Ft Vol	old growth	Bd Ft Vol	Value
R-1	$ 0.8163	42,541.0	3,736.6	38,804.4	$ 31,676.1
R-2	$ 0.8028	55,013.4	3,543.4	51,470.0	$ 41,319.6
R-3	$ 0.7992	64,622.7	3,333.9	61,288.8	$ 48,984.1
R-4	$ 0.7847	71,509.6	3,122.0	68,387.6	$ 53,667.1
R-5	$ 0.7470	41,275.9	1,962.0	39,313.9	$ 29,367.3
R-6	$ 0.7415	52,633.9	2,368.6	50,265.3	$ 37,271.0
R-7	$ 0.7368	61,033.4	2,493.3	58,540.1	$ 43,132.2
R-8	$ 0.7360	67,872.9	2,440.6	65,432.3	$ 48,156.3
C	$ 0.7235	82,732.2	2,309.3	80,422.9	$ 58,186.8
Board Foot Volume Loss/Acre					
	Damage Level:				
Regime	**0%**	**20%**	**40%**	**60%**	
R-1	-	680.7	1,361.3	2,042.0	
R-2	-	880.2	1,760.4	2,640.6	
R-3	-	1,034.0	2,067.9	3,101.9	
R-4	-	1,144.2	2,288.3	3,432.5	
R-5	-	660.4	1,320.8	1,981.2	
R-6	-	842.1	1,684.3	2,526.4	
R-7	-	976.5	1,953.1	2,929.6	
R-8	-	1,086.0	2,171.9	3,257.9	
C	-	1,323.7	2,647.4	3,971.1	
Value Loss/Acre					
	Damage Level:				
Regime	**0%**	**20%**	**40%**	**60%**	
R-1	$ -	$ 555.6	$ 1,111.2	$ 1,666.9	
R-2	$ -	$ 706.6	$ 1,413.3	$ 2,119.9	
R-3	$ -	$ 826.4	$ 1,652.8	$ 2,479.1	
R-4	$ -	$ 897.9	$ 1,795.7	$ 2,693.6	
R-5	$ -	$ 493.3	$ 986.7	$ 1,480.0	
R-6	$ -	$ 624.4	$ 1,248.9	$ 1,873.3	
R-7	$ -	$ 719.5	$ 1,439.0	$ 2,158.5	
R-8	$ -	$ 799.2	$ 1,598.5	$ 2,397.7	
C	$ -	$ 957.7	$ 1,915.4	$ 2,873.2	

Table A.8 Stand level damage analysis.

Stand Level Damage:					
	2045	**Total 2045**	**minus DF**	**2045**	**2045**
Regime	**mean $/BF**	**Bd Ft Vol**	**old growth**	**Bd Ft Vol**	**Value**
R-1	$ 0.8163	42,541.0	3,736.6	38,804.4	$ 31,676.1
R-2	$ 0.8028	55,013.4	3,543.4	51,470.0	$ 41,319.6
R-3	$ 0.7992	64,622.7	3,333.9	61,288.8	$ 48,984.1
R-4	$ 0.7847	71,509.6	3,122.0	68,387.6	$ 53,667.1
R-5	$ 0.7470	41,275.9	1,962.0	39,313.9	$ 29,367.3
R-6	$ 0.7415	52,633.9	2,368.6	50,265.3	$ 37,271.0
R-7	$ 0.7368	61,033.4	2,493.3	58,540.1	$ 43,132.2
R-8	$ 0.7360	67,872.9	2,440.6	65,432.3	$ 48,156.3
C	$ 0.7235	82,732.2	2,309.3	80,422.9	$ 58,186.8
	Board Foot Decay Loss/Acre				
Regime	**20%**	**40%**	**60%**		
R-1	3701.1	6134.4	8623.1		
R-2	4786.2	7932.9	11151.2		
R-3	5622.2	9318.6	13099.0		
R-4	6221.3	10311.7	14495.0		
R-5	3591.0	5952.0	8366.6		
R-6	4579.1	7589.8	10668.9		
R-7	5309.9	8801.0	12371.5		
R-8	5904.9	9787.3	13757.8		
C	7197.7	11930.0	16769.8		
	Value Loss/Acre				
Regime	**20%**	**40%**	**60%**		
R-1	$ 3,021	$ 5,008	$ 7,039		
R-2	$ 3,842	$ 6,368	$ 8,952		
R-3	$ 4,493	$ 7,448	$ 10,469		
R-4	$ 4,882	$ 8,092	$ 11,375		
R-5	$ 2,682	$ 4,446	$ 6,250		
R-6	$ 3,395	$ 5,628	$ 7,911		
R-7	$ 3,912	$ 6,485	$ 9,115		
R-8	$ 4,346	$ 7,203	$ 10,125		
C	$ 5,208	$ 8,631	$ 12,133		

Table A.9 Log small end diameter distribution.

LW7 Small End Diameter Distribution														
		Diameter Classes												
	YR	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
C	**1995**	119.8	224.8	100.9	35.5	19.2	1.4	2.4	1.6	1.3	0.0	0.0	0.0	0.0
	2005	97.3	124.0	176.5	61.4	30.6	16.3	1.5	2.0	0.9	1.4	0.0	0.0	0.0
	2015	75.6	101.5	134.2	90.6	53.3	36.6	13.6	1.4	2.6	0.0	1.2	0.0	0.0
	2025	37.0	78.8	91.3	118.2	82.2	43.5	27.4	10.1	2.1	1.4	1.1	0.0	0.0
	2035	41.7	52.9	70.9	114.2	89.9	48.4	33.1	21.9	4.4	1.9	1.3	1.0	0.0
	2045	16.2	58.7	58.0	84.3	100.0	52.0	35.0	26.2	18.7	2.3	0.7	1.1	0.9
1	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	0	0	7.2	30.1	31.3	19.3	1.6	2.2	1	1.5	0	0	0
	2015	0	0	0	16.1	35	42.9	15.9	1.6	3.1	0	1.5	0	0
	2025	0	0	0	4.7	21.3	35.5	38.7	13.1	2.8	1.9	1.5	0	0
	2035	0	0	0	0	16.5	22	38.7	28.2	6.2	2.7	1.8	1.4	0
	2045	0	0	0	0	4.4	21.3	21.4	32.9	26.2	3.5	1.2	1.8	1.4
2	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	0	2.8	18.9	62.6	32.8	17.3	1.6	2.2	1	1.5	0	0	0
	2015	0	0	2.7	39	61.7	42.4	15.7	1.6	3.1	0	1.5	0	0
	2025	0	0	0	17.7	63.7	43.5	34.7	12.8	2.7	1.8	1.4	0	0
	2035	0	0	0	5	40.5	42.7	47.3	27.2	6	2.6	1.8	1.4	0
	2045	0	0	0	2.4	19.4	42.4	33	32.8	30.1	3.4	1.1	1.7	1.3
3	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	0	2.8	70.2	65.2	32.6	17.2	1.6	2.1	1	1.5	0	0	0
	2015	0	0	19.1	74.2	60.6	41.7	15.5	1.6	3	0	1.4	0	0
	2025	0	0	0	50.4	85.1	46.4	36.6	12.4	2.6	1.8	1.4	0	0
	2035	0	0	0	39.4	64.3	52.1	45.5	23.9	7.9	2.5	1.7	1.3	0
	2045	0	0	0	23.6	44.5	53.2	38.2	31	28.5	3.2	1	1.6	1.2
4	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	0	10.1	120	64.7	32.3	17.1	1.6	2.1	1	1.5	0	0	0
	2015	0	0	43	103	59.5	40.9	15.2	1.5	3	0	1.4	0	0
	2025	0	0	9.7	92.3	83.4	48.6	35.4	12	2.5	1.7	1.3	0	0
	2035	0	0	3	68.7	87.2	56.6	38	25.5	7.6	2.4	1.6	1.2	0
	2045	0	0	0	46.3	71.9	56.2	41	29.3	26.8	3	1	1.5	1.2

Table A.9 (Continued)

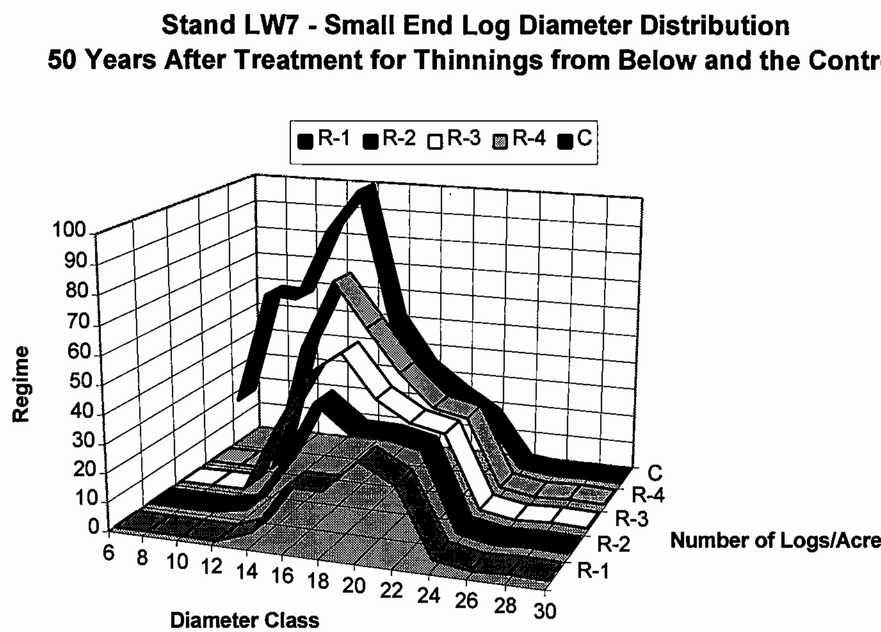
		Diameter Classes												
	YR	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
5	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	22.7	32.4	51.2	18.8	7.3	5.2	0.4	0.5	0.2	0.4	0	0	0
	2015	11.7	26.2	37.6	38.1	18.4	11.8	5.2	0.4	0.8	0	0.4	0	0
	2025	12.9	20.3	24.7	46.2	36.7	17.9	12.4	4.5	0.7	0.5	0.2	0.2	0
	2035	6.5	16.3	19	25.1	54	30.5	15.7	12.1	3.3	0.7	0.5	0.4	0
	2045	2.8	10.4	20.8	16.1	42.2	37.9	24.9	13.2	12	2.1	0.7	0.4	0.3
6	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	33.6	45.9	67.6	26.1	10.1	7.2	0.6	0.7	0.3	0.5	0	0	0
	2015	18.7	33.6	56.9	47.8	24.4	16.1	7.1	0.5	1.1	0	0.5	0	0
	2025	11.6	29.8	34.9	60.1	48.1	21.6	17.7	5.2	0.9	0.6	0.5	0	0
	2035	8.9	22.1	29.1	39.7	65.5	39	18.4	16.1	4.4	0.9	0.6	0.5	0
	2045	5.7	15.4	22.4	30.8	53.8	47.9	27.8	16.1	15.8	3.3	0.4	0.6	0.5
7	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	41.7	58.7	86.4	33.4	13.7	8.4	0.7	1	0.4	0.7	0	0	0
	2015	23.9	44	73.3	57.3	31	21.5	7.9	0.7	1.3	0	0.6	0	0
	2025	28.4	31.1	42.3	71.4	54.3	28.5	20.7	6.6	1.2	0.8	0.6	0	0
	2035	9.4	33.1	37	49.7	79	42.4	22.3	19.5	4.4	1.1	0.7	0.6	0
	2045	7	29	26.2	37.7	66.5	48	34.7	19.2	16.8	4	0.5	0.7	0.5
8	**1995**	119.8	225	101	35.5	19.2	1.4	2.4	1.6	1.3	0	0	0	0
	2005	52.4	70.1	105	38.7	16.7	10.2	0.9	1.2	0.5	0.8	0	0	0
	2015	40.1	47.3	88.5	62.7	39	24	9.5	0.8	1.6	0	0.8	0	0
	2025	29.5	40.1	52.6	80.2	65.2	31.1	22.8	7.8	1.4	0.9	0.7	0	0
	2035	13.5	47	35.4	69.9	81.5	42	24.4	22.8	5.1	1.3	0.9	0.7	0
	2045	12.1	29.9	30.5	45.6	84.7	51.4	33.4	20.2	18	4.6	0.5	0.8	0.6

Table A.9 (Continued)

LW7: Small end log diameter distribution/acre 50 years after treatment													
	Diameter Classes												
Regime	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
R-1	0	0	0	0	4.4	21.3	21.4	32.9	26.2	3.5	1.2	1.8	1.4
R-2	0	0	0	2.4	19.4	42.4	33	32.8	30.1	3.4	1.1	1.7	1.3
R-3	0	0	0	23.6	44.5	53.2	38.2	31	28.5	3.2	1	1.6	1.2
R-4	0	0	0	46.3	71.9	56.2	41	29.3	26.8	3	1	1.5	1.2
R-5	2.8	10.4	20.8	16.1	42.2	37.9	24.9	13.2	12	2.1	0.7	0.4	0.3
R-6	5.7	15.4	22.4	30.8	53.8	47.9	27.8	16.1	15.8	3.3	0.4	0.6	0.5
R-7	7	29	26.2	37.7	66.5	48	34.7	19.2	16.8	4	0.5	0.7	0.5
R-8	12	29.9	30.5	45.6	84.7	51.4	33.4	20.2	18	4.6	0.5	0.8	0.6
C	16	58.7	58	84.3	100	52	35	26.2	18.7	2.3	0.7	1.1	0.9

Figure A. Log small end diameter distribution (a) stands thinned from below and (b) stands thinned proportionally.

a)



(b)

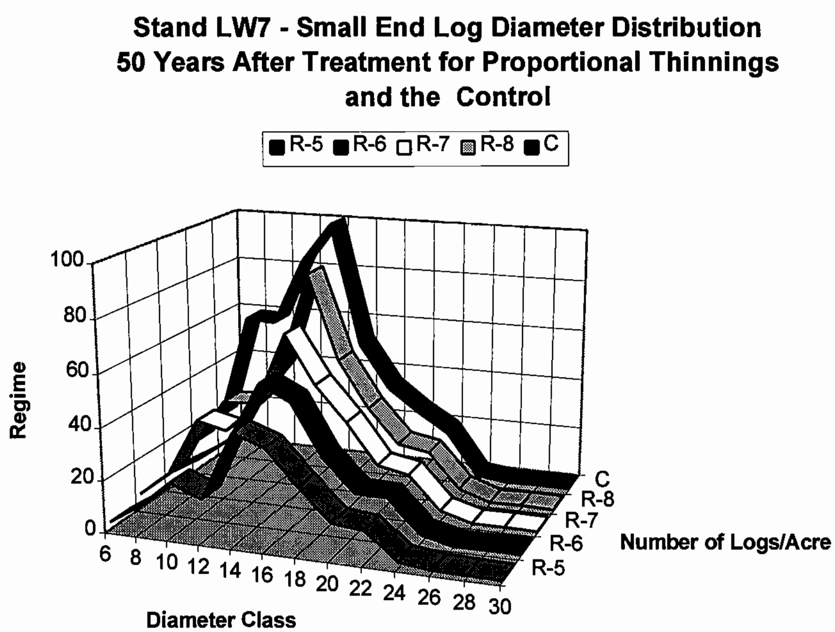


Table A.10 Branch presence analysis data.

	Branch Status in First Log:		
	Value (absolute) per Acre 50 years after thinning		
Regime	**1995 Level**	**Partial Removal**	**Total Removal**
R-1	$ 31,676.1	$ 34,168.8	$ 35,282.5
R-2	$ 41,319.6	$ 44,594.1	$ 45,657.5
R-3	$ 48,984.1	$ 52,546.0	$ 53,553.4
R-4	$ 53,667.1	$ 57,295.6	$ 58,243.3
R-5	$ 29,367.3	$ 31,337.5	$ 32,088.9
R-6	$ 37,271.0	$ 39,785.3	$ 40,761.7
R-7	$ 43,132.2	$ 45,937.3	$ 47,121.6
R-8	$ 48,156.3	$ 51,085.0	$ 52,448.8
C	$ 58,186.8	$ 61,179.7	$ 61,896.5
	Benefit gained per acre from Partial Branch removal in first log:		
		(4% Discount rate)	**(6% Discount rate)**
Regime	**Absolute Value**	**PNW**	**PNW**
R-1	$ 2,492.7	$ 350.8	$ 135.3
R-2	$ 3,274.5	$ 460.8	$ 177.8
R-3	$ 3,561.9	$ 501.2	$ 193.4
R-4	$ 3,628.5	$ 510.6	$ 197.0
R-5	$ 1,970.2	$ 277.2	$ 107.0
R-6	$ 2,514.3	$ 353.8	$ 136.5
R-7	$ 2,805.1	$ 394.7	$ 152.3
R-8	$ 2,928.7	$ 412.1	$ 159.0
C	$ 2,992.9	$ 421.1	$ 162.5
	Benefit gained per acre from Total Branch Removal in first log:		
		(4% Discount rate)	**(6% Discount rate)**
Regime	**Absolute Value**	**PNW**	**PNW**
R-1	$ 3,606.4	$ 507.5	$ 195.8
R-2	$ 4,337.9	$ 610.4	$ 235.5
R-3	$ 4,569.3	$ 643.0	$ 248.1
R-4	$ 4,576.2	$ 643.9	$ 248.4
R-5	$ 2,721.6	$ 383.0	$ 147.8
R-6	$ 3,490.7	$ 491.2	$ 189.5
R-7	$ 3,989.4	$ 561.4	$ 216.6
R-8	$ 4,292.5	$ 604.0	$ 233.0
C	$ 3,709.7	$ 522.0	$ 201.4